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The Journal of Bone and Joint Surgery

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The Journal of Bone and Joint Surgery*

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ELLIOTT GRAY BRACKETT

In the death of Elliott Gray Brackett one of the last links in the chain that binds the organizers of the American Orthopaedic Association to its present membership has been broken. Although he was not a founder, he was one of the earliest to be admitted to membership, and he served the Association more years in various official capacities than anyone else.

To those who were privileged to know him intimately, there is nothing one need say to remind them of their loss, individually and as an organization; to those not so privileged, nothing that *anyone* could say would adequately express the feeling of respect and affection his close friends and associates had for him.

As one who, from the very beginning of his membership in the Association, had shown a very keen interest in its objectives and was instrumental in helping to achieve them, his activities on behalf of this body are a challenge to the present membership.

If the American Orthopaedic Association means anything to its members and if it has figured at all in making the specialty respected in this country and abroad, it is due in no small measure to the group of pioneers who developed an especial interest in the understanding and treatment of chronic diseases in bones and joints, and of related conditions, that appeared to call for special training on the part of those who were to treat them. To this group Dr. Brackett attached himself in 1889, two years after the founding of the Association.

It was but natural that he should have chosen this line of work, for a personal experience with a crippling affection, which confined him to bed for a year while he was a student in Harvard Medical School, coupled with the fact that Dr. Edward H. Bradford took care of him through this illness, would have made a man of Dr. Brackett's sympathies turn to a specialty where he could be of the greatest service. In making this decision, his judgment has been amply justified.

As an illustration of how obstacles only served to spur him to greater effort, the fact may be recalled that with the help of a classmate, who

brought his class work to him during that period, he completed his medical school course on time. Having finished that, in 1886, he received an internship at the Boston City Hospital, and, although he was on crutches, he did not miss a day of his service. These facts are noted because they have a bearing on the way he handled his patients and dealt with many difficult situations. He never gave up.

Four years after becoming a member of the Association, he was elected Treasurer. He served the Association in this capacity for thirteen years. In 1905 he held the office of President. He was on the Membership Committee for eight years, was a member of the Executive Committee for at least thirty-five years, and Editor of *The Journal* for twenty years. In all, he gave important service to the Association for forty-three years. Without doubt the most important was his tenure of the Editorship, which covered the period from June 1921 through December 1942.

His sterling qualities were duly valued and respected, as has been abundantly evidenced by the confidence reposed in him by the Executive Committee, and through them by the entire membership of the Association.

The years immediately following the foundation of the Association, in 1887, were years filled with responsibility for it by the members. Their number was limited and their distribution throughout the country was not very wide. It was their task to raise the specialty to a respected position among the other specialties. At that time neither the profession nor the public looked with much favor upon specialization, and in certain quarters prejudice against it had to be overcome by tact, as well as by demonstrating the fact that many chronic osseous conditions, whether congenital, paralytic, or static, were better handled by the orthopaedically trained specialist than by the general surgeon.

As more and more men became interested in the problems of orthopaedic surgeons, their distribution over this country and Canada became more general; and, during the earlier years, the annual meetings of the Association were held in cities to which the specialty was a novelty and in which a pioneer in orthopaedic surgery had recently located. This policy was advocated by Dr. Brackett in his Presidential Address in 1905.

Holding such scientific sessions in those localities had a great deal to do with dispelling antipathy to the specialty. At these meetings young men were brought in contact with the group who in the early days of the organization were most prominent in shaping its destiny. Conspicuous among them was Dr. Brackett.

His almost continuous membership, on one committee or another, resulted in a nearly perfect record of attendance at the annual sessions. For this reason he had opportunity to become widely known to the succession of new members.

In spite of all his committee cares, he was a not infrequent contributor to the scientific discussions, and the field covered by his published papers represents an interest in a wide variety of orthopaedic subjects. His

Photograph by Bachrach

ELLIOTT GRAY BRACKETT

April 6, 1860—December 29, 1942

formal papers were always well considered and conservative; his discussions were pertinent, based as they were on a broad experience in hospital and private practice. His records were among the best the writer has ever seen. His influence was manifest in his wise counsel in committees and conferences.

Dr. Brackett was elected Editor of *The Journal* in 1921. With the issue of the following January it again became a quarterly and the name was changed to *The Journal of Bone and Joint Surgery*.

When he took over the Editorship, *The Journal* had not progressed very far beyond the Transactions stage of its evolution. At that stage it was practically mandatory that all papers read at the scientific sessions of the Association be published. It often happened that under this rule papers were published that were not worthy of a journal having a nation-wide circulation, and the new Editor recognized this. Early in his administration an Advisory Editorial Staff was organized. This included representative men in different parts of the country who rendered a real service by stimulating interest in their respective communities, resulting not only in new subscribers and advertisers, but also in future contributors.

The next step was the appointment of a group of Foreign Editors who kept him informed about the development of the specialty in their countries, from time to time sending in reports of meetings and papers by their colleagues. This added to the international character of *The Journal*, a matter which was always very much in Dr. Brackett's mind, for he believed that such a publication could be a real factor in the development of better understanding and closer cooperation between nations. It was, therefore, a special satisfaction to him when contributions began to come from representative surgeons in different countries, many of them men he had met personally during his summers in Europe. From the correspondence with these foreign contributors developed acquaintances which led to real and lasting friendships, strengthened by the opportunity of seeing these men at work in their own hospitals. He planned his vacations so that he could be present at orthopaedic congresses in France, Belgium, Italy, Germany, Czecho-Slovakia, and Switzerland. Perhaps one of the greatest pleasures which came from these contacts was his visit to Leningrad in the summer of 1936 when he had the opportunity of meeting Prof. Henry Turner, with whom a warm friendship had developed through years of correspondence, and of seeing the remarkable work for crippled children which had resulted from the labors of this pioneer, a man of British parentage who had devoted his life to the development of orthopaedic surgery in Russia. On this trip Dr. Brackett visited hospitals in Leningrad and Moscow, and spent some time with the officials of the U.S.S.R. Society for Cultural Relations with Foreign Countries, through whose interest many of the contacts of *The Journal* with Soviet publications had been made possible.

The number of papers offered for publication gradually increased, so

that more and more work came to the editorial office; and two steps were taken to assist the Editor,—the election of a Program Committee that exercised some supervision over the standard of the papers presented at the annual meetings, and the creation of a Board of Associate Editors. Since the appointment of the latter, all papers have been submitted to this body, and gradually the Editor impressed upon them his ideals and standards for a journal.

The Journal was of vital concern to Dr. Brackett. No one not intimately associated with him has any idea how much time and thought he gave to it. To him it was not merely a rostrum from which an author might exploit his ideas. He must present something that was new, or at least, if not wholly new, it must be presented in a better form than ever before. He tried to impress upon the writers that brevity should be an accompaniment of clarity in expression, and that it was a mistake to rush into print before sufficient time had elapsed for a definite opinion to be formed as to the soundness of any position taken.

His intimate acquaintance with the membership of the Association for so many consecutive years made it possible for him to be of the greatest assistance to younger men sending in papers for publication. He spared no pains in his efforts to have the papers he thought worthy of publication brought up to the standard he had set. Without doubt it is in large part due to his insistence upon the observance of these rules that *The Journal* occupies the position it does today.

When he became Editor the total list of subscribers numbered 797. At the time of his death the number of paid subscriptions was over 3500. During the twenty years of his Editorship, the budget of *The Journal* was increased eight-fold.

The realization of some of his aspirations for *The Journal* has come through the broadening of the field of its usefulness, as shown by the fact that there has been a steady increase in the number of foreign, as well as domestic, subscribers. At the end of 1939 (the beginning of the war), *The Journal* was being mailed regularly to subscribers in sixty different countries outside the United States and Canada.

For the first five years that Dr. Brackett had charge of *The Journal*, he provided office space in his own house. He never received salary for his work, and at the time the Association made the first attempt to show their appreciation of his services on their behalf in the form of an honorarium, he persuaded the Executive Committee to put the sum into a fund to be used at the discretion of the Editor to defray the expense of illustrations in cases where it seemed right that it should be so employed. This sum was set up by the Association as the Elliott G. Brackett Endowment Fund. On the occasion of his eightieth birthday, a second attempt was made by the Association to show their esteem, and a large number of letters were written to him, and a gift was made with the request that it be used by him personally.

In spite of all that he was giving to his practice and to the Association,

he found time to serve his community in its hospitals and in promoting many movements to aid the physically handicapped. He was identified with various Boston hospitals,—in his early years at the House of the Good Samaritan, later as Orthopaedic Surgeon at the Children's Hospital. In 1911 he became Chief of the Orthopaedic Service at the Massachusetts General Hospital and continued in that position until 1918 when he resigned to go into war service. At the time of his death he was Orthopaedic Surgeon at the Faulkner Hospital.

At the end of the Spanish-American War in July, 1898, he was sent to Cuba as representative of the Massachusetts Volunteer Aid Association. His assignment was to receive supplies sent on hospital ships and to determine the needs of the men. His first concern was for the sick among our troops ready to be evacuated to the United States and he made provision for their care on transports. Then, at the request of General Wood, he took charge of a hospital in Santiago and also organized work for the care of the sick in the city where serious epidemics had developed.

Answering the call of his country in World War I, he was largely responsible for the training of the orthopaedic personnel and for the determination of where they should be located after their preparation had been completed. He himself, eventually, was sent overseas, returning with the rank of Colonel.

At the invitation of the China Medical Board of The Rockefeller Foundation, who learned that he contemplated a trip to China in 1922, he gave a series of lectures at the Peking Union Medical College and in one or two other medical centers.

The impress of such a life, upon those who have been privileged to experience it, is an indelible one, and should serve to inspire those who remain to carry on with a determination to see that the ideals he cherished for the Association, and that he strove for in all his relations with his fellow men, be fought for as he himself would have fought for them.

AVASCULAR NECROSIS OF BONE

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In the Forty-Fourth Report of Progress in Orthopedic Surgery, published by the American Medical Association in 1931, the editors made the following comment on the condition most commonly known as coxa plana or Perthes' disease: "We question whether it is often necessary to employ immobilization even in the acute stage of this condition. The disease is frequently symptomless, and we do not believe that any evidence has been adduced to show that its course can be modified by treatment." In England, at that time, the general view held by orthopaedic surgeons was expressed by Platt in the following words: "There are no definite reasons for the adoption of a prolonged period of immobilization".

From the study of the serial roentgenograms in thirty-three cases of this disease—which will be alluded to as Legg's disease, since Legg first described it in 1909—the author concluded that roentgenograms supply very definite evidence in support of immobilization for a long period. In a paper read before the Medical Society of London in March 1932, the author demonstrated the roentgenograms of these cases and showed that: (1) for upwards of four years, until the last dense island had been replaced by normally ossified bone, the bone of the affected joint was plastic and could be deformed by pressure; and (2) if the joint was immobilized during the plastic stage, although the series of changes was uninterrupted, organization of the affected bone proceeded, and no deformity occurred. In the subsequent discussion, McCrae Aitken supplied clinical evidence which confirmed the author's roentgenographic findings. In 1934, after correlating the serial roentgenographic appearance in some seventy-one cases, the writer was able to draw up the time table which appears as Table I, showing the sequence of changes in twelve stages that characterize the disease from its inception to its complete healing. This sequence of changes has been confirmed by the subsequent examinations of fifty additional cases.

In 1934, Danforth published the case notes and roentgenograms of five patients who had been given freedom from weight-bearing during the long period of bone plasticity, and his findings lent further support to the suggestions made two years previously by the present author.

In 1938, Waldenström, in a paper describing the first stages of coxa plana, stated: "The most important consideration is to treat these cases purely conservatively. The patients should be given from one to two months' rest in bed, after which they may be up and about on crutches for at least one year." However, in a footnote, he stated that after the paper had been presented Danforth had shown him the roentgenograms

TABLE I

ROENTGENOGRAPHIC CHANGES IN LEGG'S DISEASE FROM INCEPTION TO COMPLETE HEALING

Roentgenographic Appearances	Age of Lesion Judged from Onset of First Symptoms	Condition of Bone
1. Increase in density of femoral capital epiphysis 2. Relative increase in joint space 3. Osteoporosis of diaphysis	2 to 3 months	Becoming plastic
4. Compression and impression fractures of epiphysis 5. Appearance of fragmentation 6. Compression and flattening of fragments 7. Gradual absorption of dense fragments 8. Compression and expansion of proximal end of diaphysis	3 to 18 months	Plastic
9. First appearance of regeneration in epiphysis in which dense fragments are undergoing absorption 10. Absorption of last dense nucleus and appearance of circumscribed area of osteoporosis in its place 11. Increased deposition of calcium and obliteration of osteoporotic zone in diaphysis	1½ to 4 years	Plastic
12. Assumption by epiphysis of roentgenographic appearance of normal bone	During or after 4th year	Consolidated

of two patients who had been treated with rest in bed for one year or more and then had been allowed to walk with crutches, the results in these two cases being better than those which he had obtained. Waldenström stated that he intended to try this method of treatment.

Gill, in 1940, stated: "But after Danforth's paper in 1934, we began to follow his method of prolonged rest in bed. . . . When we are able to carry out this method without interruption, the end results are practically perfect hips." His paper contained serial roentgenograms of a number of cases, which confirmed not only the opinions that the author had previously formed from his study of serial roentgenograms, but also the time table incorporated in his book, published in 1935.

More recently, it has been stated that Legg's disease is not an osteochondritis, but is simply an avascular necrosis; also that osteochondritis and

avascular necrosis are one and the same condition and are indistinguishable. Axhausen, in 1923, suggested that avascular necrosis produced by mycotic emboli was one of the features in osteochondritis. . However, the writer hopes to show that the latter term embraces also the more important concomitant living process, producing decalcification and a plasticity in the neighboring bone, which permits of deformity when pressure is applied. In some of these cases it is osteoporosis which dominates the picture, and there is no sign of a necrotic fragment. It was pointed out by Phemister in 1930 that "Histologically the majority of these lesions appear to have something more back of them than a simple bland embolus or injury cutting off the circulation and producing aseptic necrosis". The roentgenographic appearances of the successful autogenous bone graft do not indicate that it behaves as a necrotic fragment, as has been suggested. The relative rapidity (often within from three to six months) with which the graft is incorporated into the bone that it bridges suggests that it retains life throughout. These roentgenographic appearances do not include the hypercalcification and fragmentation that are seen in osteochondritis. It has been stated that if the avascular fragment carries with it the articular cartilage of a joint, the outlook is wholly changed. Replacement of the hyaline cartilage with fibrous tissue or with an imperfect fibrocartilage is almost inevitable, and survival of the joint is relatively rare. This is certainly not the clinical or the roentgenographic finding in Legg's disease; *the characteristic feature of the carefully treated case is the absence of change in the articular surface and a return to normal function.* Quoting from Waldenström's article in 1938, "It should be remembered that most cases heal with a deformity which is only slightly troublesome, at least up to fifty years of age," and repeating Gill's statement "the end results are practically perfect hips".

DIFFERENTIAL ROENTGENOGRAPHIC APPEARANCES

The evidence as to the causation of osteochondritis of the hip is not conclusive. Trauma would appear to be an important factor in many cases, but it is an insufficient agent in many others. It has been held that "Whether the source of deprivation of blood is obvious, as in fracture or dislocation of the joint, or concealed, as in traumatic or toxic thrombosis, the sequelae are the same". Roentgenographically, they are certainly not the same.

Congenital Dislocation of the Femoral Head and Legg's Disease

The changes in the femoral head and neck which have been forcibly twisted and turned during attempts to reduce a congenital dislocation are not roentgenographically identical with those seen in Legg's disease. The serial roentgenographic appearances of fragmentation following surgical trauma to the dislocated femoral head are not identical with those in Legg's disease, except as in the cases to be cited later. In Legg's disease the appearance of fragmentation is seen in the destructive phase, whereas

in the case of surgical trauma it occurs in the regenerative phase. In the latter condition, the fragmentation resembles the ossification of the femoral head in hypothyroidism, but the epiphyses will not stand up to normal weight-bearing and so are deformed, as are the epiphyses in Legg's disease, but in Legg's disease the deformity occurs during disintegration rather than during reorganization. The changes following surgical trauma take place more rapidly than do those in Legg's disease, and are sometimes associated with serious damage to the growth cartilage, resulting in marked stunting of growth,—a feature absent from Legg's disease. The author believes that the changes which follow forcible reduction of the femoral head in healthy children are due solely to the trauma involved; the additional debilitating factor present in Legg's disease is usually absent, hence the readier healing. However, the writer has seen typical Legg's disease develop in the opposite normal hip during recumbent treatment of the dislocated hip, which did not undergo any such change.

Dissolution of Epiphyseal Union

It is very rare for the femoral diaphysis to be displaced from the capital epiphysis during forcible manipulation (the author has seen it in two cases only), for in this instance some additional debilitating factor is necessary to weaken the bond at the growth cartilage. When, however, such a weakened bond is broken by trauma and the epiphysis is so much displaced that its blood supply is cut off, the changes which it undergoes are not those seen either in the simple trauma described or in Legg's disease. However, the author has witnessed and recorded the typical serial time table of osteochondritis initiated in the bone forming the roof of the acetabulum in a case of slipped epiphysis, where fusion of the epiphysis and diaphysis occurred in the displaced position without any sign of avascular necrosis of the femoral head or damage to the articular cartilage. Healing of the slipped epiphysis is associated with fusion of the epiphysis and diaphysis. This is not observed in Legg's disease, but it sometimes occurs as the result of trauma entailed in reducing congenital dislocation in which secondary changes in the injured epiphysis somewhat resemble those in Legg's disease. The mass necrosis of the femoral head and the marked pressure deformities of the plastic bone of the neck, which occur in some cases after dissolution of the bond between the diaphysis and the epiphysis, create quite a different picture, and one in which the articular cartilage is often involved.

In 1933 the author described a preslipping stage of slipped epiphysis, denoted by the roentgenographic evidence of pathological changes in the growth cartilage which unites the diaphysis with the epiphysis. Briefly, this consists of reaction in the bone bordering both sides of the growth cartilage, resulting in an apparent excavation of the bony epiphyseal border and erosion of the diaphyseal surface. The outline of the unaffected epiphyseal border is rendered clearer, but, in contrast, the diaphyseal surface becomes ill-defined and woolly, while the metaphysis itself appears

to be thickened. If this evidence is heeded and the joint is protected, the slipping and the possibility of subsequent destructive changes might be prevented. Recently it has been asserted that no such preslipping stage exists, and that the failure to detect slipping is due to the fact that no lateral roentgenogram has been taken. The writer agrees that slipping may not be noticed in the anteroposterior roentgenogram as readily as in the lateral view. The clinical history of the typical case supports the author's roentgenographic findings. Symptoms are often present for months before the actual dissolution takes place, usually without any history of trauma, and roentgenograms at this stage will not show displacement. The latter often occurs without warning, and the symptoms become suddenly more prominent, frequently as a result of trauma which would not have damaged a normal joint. Anteroposterior and lateral roentgenograms will then show the displacement, one projection sometimes demonstrating it better than the other. In the cases of slipped epiphysis which the writer had previously reported in the preslipping stage, no sign of slipping was shown in the anteroposterior or lateral x-rays.

The femoral capital epiphysis may be detached and rendered avascular by forcible abduction during the treatment of rachitic coxa vara.

Fractures of the Femoral Neck

Fractures of the neck of the femur in children are much more rare than either Legg's disease or dissolution of the epiphyseal union. The author has seen only fifteen such fractures during the past twenty years. The majority of these were in the base of the neck; more than half of them showed vascular changes, a finding which is supported by Brandon Carrell and W. B. Carrell and by others. The roentgenograms of such lesions shortly after the accident do not show any difference in the density of the fragments, but, after about one month, a zone of increased density having an ill-defined border may be seen against the fractured surface on the proximal fragment, denoting interference with vascularity. During the next month, and for a varying number of months afterward, the whole of the proximal fragment retains its density, while in the trochanteric area and in the shaft, diminished density gives evidence of decalcification. The neck of the proximal fragment may show an added density with blurring of the outline of the fractured end of its cancellous structure. Unless the fragments are sufficiently immobilized at this time, coxa vara deformity will develop, as the bone is plastic. Union of the fragments may be noted at the end of about three months, after which the density of the neck fragment gradually disappears. For some months, the femoral head may show uneven density; the subarticular bone may appear to be almost completely decalcified. Pressure during this time appears to result in damage to the articular cartilage, with subsequent arthritic changes. If the head and neck fragments retain their density and the fractured surface its sharpness of contour, avascular necrosis is established and several years may elapse before restoration is complete.

Fractures of the femoral neck in adults are frequently associated with localized necrosis of the head fragment, particularly if this has not been immobilized.

Dislocation of the Hip Joint

The trauma associated with the production and reduction of dislocations of the hip joint is usually the cause of serious damage to the vascularity of the proximal end of the femur. This is a factor which is only too commonly overlooked, and the roentgenographic appearances of the bones and joints are in some measure responsible. So little alteration in the characteristic outlines and details may be shown in the roentgenograms taken several months after the reduction that the changes are undetected. The author has seen such roentgenograms exhibited in court by expert witnesses as evidence that the patient had sustained no damage to the joint, and that the disability of which he complained was "functional". However, these changes, although apparently insignificant—perhaps a slight degree of osteoporosis with or without a faint hazy opacity within the capsule, due to a deposit of amorphous calcium—are the indications, which, if they are neglected and the limb is permitted to function, presage the disintegration of the joint. Work or strenuous exercise would undoubtedly increase the extent of the damage; whereas, if these changes were recognized early and the joint was immobilized until such time as the roentgenographic appearance indicated a return to the normal, the joint would in a large measure be preserved.

Fractures of the Acetabulum

Fractures of the acetabulum, even when the acetabulum has been perforated by the femoral head, appear to consolidate with new bone more massive and dense than in any other site. It is unusual for such fractures to be associated with avascular necrosis, although the author has seen it resulting from the operative building up of the acetabular roof in cases of congenital dislocation.

Osteochondritis Dissecans (König)

This lesion is most commonly encountered in the articular surface of the medial femoral condyle, but the author has observed it in the lateral femoral condyle, the femoral capital epiphysis, the capitellum, the head of the radius, the humerus, the first metatarsal, and the lower end of the tibia. From a study of the serial roentgenograms and the operative findings in a number of cases, the writer's conception of the lesion is different from that usually described. The lesion, he believes, is produced in the first instance by injury to a localized segment of the articular surface embracing either the cartilage alone or the cartilage and the subarticular bone. It is possible that a breach in the surface permits the permeation of synovial fluid, and that this tends to inhibit fusion. The affected fragment is not usually completely cut off from its blood supply; in the

young person it may continue to grow within the bed of the parent bone. The roentgenographic findings vary with the extent and the nature of the lesion. If the cartilage only has been injured, the articular surface may appear to be normal; later, a small depression may be noted. In this depression a small ossicle develops. If the lesion is symptomless, its discovery may be made by chance during the taking of roentgenograms for some entirely different reason, as when the joint is x-rayed for comparison with the opposite affected joint. When symptoms develop, roentgenograms may reveal the ossicle a little denser than the parent bone (it is becoming avascular) or the latter may show a denser outline for its bed. After the symptoms have persisted for some months, roentgenograms may disclose that the denser fragment, in which the cancellous structure appears to be obliterated, is losing its sharp outline and uniformity of density, while the bone surrounding its bed may show such marked localized osteoporosis that the suspicion of tuberculous caries may be aroused. It is the author's belief that the increased density of the ossicle and its subsequent changes are due to avascular necrosis, an opinion which is supported by the reactive changes that develop concomitantly in the surrounding bone. Removal of this dead fragment usually brings an end to the reactive changes in the surrounding bone, and leads to its recalcification. In some cases such ossicles appear to have a rather different history. They are found in joints in which the epiphysis has developed from multiple ossific nuclei, as in hypothyroidism and chondro-osteodystrophy, or in which the regenerating fragments of the epiphysis are injured and sequestrated, as in osteochondritis. Such separate ossicles are frequently seen in the second metatarsophalangeal joint following Köhler's disease, and occasionally in the hip joint following Legg's disease.

The history of the fragment separated by trauma is similar to that of the bone graft, except for the special factors which operate on an articular surface. The fragment may undergo any one of the following four changes:

1. It may fuse and become incorporated with and indistinguishable from the parent bone.

2. It may be completely absorbed, leaving no trace of ossification in the gap which it filled.

3. It may become necrotic and undergo what has been referred to as creeping substitution, in which it may lose the sharp internal definition of its structure, take on an added density and later the appearance of fragmentation, and, after the absorption of the denser fragments, may experience a regeneration and development, which may be complete as in (1) or defective in part as in (2); the latter condition is probably due to trauma while the fragment was still plastic. These changes occur with concomitant decalcification and recalcification of the adjacent parent bone.

4. It may fail to show any regenerative or destructive properties and may eventually be extruded into the joint as a loose body.

SIGNIFICANCE OF AVASCULAR NECROSIS

In regard to the advisability of operative nailing in fractures of the femoral neck, Watson-Jones has stated: "The treatment of this fracture is entirely dominated by the incidence of avascular necrosis. If this complication arises the result is a failure. . . . It is quite erroneous to believe that the nail itself causes necrosis. . . . If there is proof of necrosis of the head, nailing should not be attempted even if the fracture is only six or eight weeks old. The attempt will probably fail because the necrotic bone is too friable to hold the nail. It is better to perform an osteotomy of the femur of the Lorenz or Schanz type in which an arthroplasty is established between the femur and the pelvis, the head remaining sequestered and immobile in the acetabulum." From this it would seem that the contribution required from roentgenology is recognition of avascular necrosis, since it cannot be recognized in any other way.

ROENTGENOGRAPHIC EVIDENCE OF AVASCULAR NECROSIS

If a fragment of bone is deprived of its blood supply, it will not exhibit the decalcification of the adjacent bone, which results from the disuse occasioned by the injury; consequently, in the roentgenogram it will appear denser than the living bone. This relative density does not indicate that the fragment is necrotic, for it is seen in fractures and in the successful autogenous bone graft which, for a time after its insertion, retains its density, although the fragments which it bridges undergo decalcification. When the graft has taken, it, too, loses calcium and becomes of the density of the recipient bone. With increased function, the mended bone wholly increases in density. There is no suggestion of fragmentation or hypercalcification; it appears that living cells have persisted throughout the whole graft, being sustained by the plasma which has bathed them until revascularization has been established. We cannot say that, because a fragment of bone exhibits this temporary retention of calcium, it is necrotic.

If a bone fragment is necrotic, it is friable and, like other dead tissue, may and often does attract calcium from the plasma and causes a drain on the calcium of adjacent bone. Therefore, the necrotic fragment acquires an added density which can be recognized by comparison with normal bone in the opposite limb. As long as this hypercalcification persists, the part exhibiting it must be regarded as necrotic. In bone tumors which have caused necrosis of a fragment, the hypercalcification persists for the remainder of the patient's life, but, if the necrosis is due to vascular disturbance brought about by trauma, the fragments are gradually infiltrated with living cells and the bone takes on abnormal plasticity, the infiltration showing as ill-defined zones of decalcification often more marked at the periphery. Some authorities deny that this hypercalcification occurs.

The basal epiphysis of one or more of the terminal phalanges of the hand may sometimes exhibit an abnormal density, which has led to the

diagnosis of avascular necrosis of the epiphysis. This is an error. It is a variation in the ossification of the terminal phalanges, — a variation which is not associated with any pathological changes. Therefore, not all bone exhibiting hypercalcification is necrotic. In addition, there must be sequestration of the fragment, which retains its sharp outline or evidence of friability and later so-called creeping substitution, in which the denser fragments are apparently undergoing dissolution. This phenomenon, which the author calls the ossilating interchange of calcium between the necrotic and the adjacent living bone, can be best seen in Köhler's disease of the tarsal navicular. The blood supply to the navicular is apparently cut off; the bone gradually attracts calcium from the neighboring tarsal bones, so that they show progressive decalcification as the navicular increases in density. The dense bone is compressed and later may show the appearance of fragmentation with gradual dissolution of the fragments. The bone is regenerated from the periphery, and, as the dense islands disappear, the other tarsal bones increase in density, the last area to acquire normal density often being the site of the last dense island. If the avascular necrotic bone is in the process of substitution, the trauma of normal function may cause a localized check to the process; reossification of the affected area may fail, or the sequence of changes of osteochondritis may reappear within it. The new bone which has been substituted for the necrotic fragment and adjacent plastic bone is sometimes of a very coarse cancellous structure. The question may be asked: When and for how long can one recognize this increased density? The answer is: As long as the fragment is avascular and necrotic it will retain its density; it will gradually lose it as it becomes infiltrated with living cells. It is not a fleeting process, for, in the case of the necrotic femoral head in any of the conditions which have been considered, the roentgenograms will afford evidence of contrasted density from the first or second month until the third or fourth year. In the case of the infant tarsal navicular, in which the regeneration is quicker, the hypercalcification is recognizable for about one year. In the proximal necrotic fragment of the carpal navicular, it may be detected continuously for from eighteen to twenty-four months.

Although it has been stated that in Legg's disease, if the hip is immobilized so that disuse calcification arises and many roentgenograms are taken at weekly or fortnightly intervals, one film will show failure of decalcification of the epiphysis. This stage is transient and may easily be overlooked. The roentgenographic indication is that it is not even necessary to immobilize the hip joint in Legg's disease to secure contrast density in the compressed or fragmented epiphysis; it is often found in the first roentgenogram of the active child and, as has been indicated, persists for upwards of four years.

PINNING OF THE FEMORAL NECK

As in the first month roentgenography affords little or no evidence of avascular necrosis, and since during this period it is usual for the pin to

be inserted, the surgeon can have no knowledge whether or not aseptic necrosis exists when he operates. Further, because it is pinned and function is permitted soon after, the living bone will not lose its calcium, and the contrast density of the fragment which has had its circulation disturbed will not be revealed by the roentgenogram. The first and only indication of this condition after several months may be fracture and compression of the superior surface of the femoral head. The pain and discomfort associated with this, leading to removal of the pin and a period of freedom from weight-bearing, brings about some decalcification of the living bone, and the contrasted density of the necrotic fragment may then become apparent in the roentgenogram and persist until the fragment has been absorbed or removed. During revascularization of the fragment, it and the adjacent bone become plastic and may be deformed by pressure; the pin may cut through the femoral head and neck and even the bony wall of the pelvis as through cheese. Destructive changes in the articular cartilage of the compressed femoral head, disintegration of the bone, and deformity of the joint surfaces ultimately develop. Intrusion of the pin into the joint surface results in erosion of the articular surface. Absorption may be seen along the track of the pin, which is loosened. The pin may be extruded, and, because the fractured surface is no longer protected, displacement may occur. The author has not seen any case treated by external splinting in which the femoral head has collapsed and undergone the rapid disorganization seen in some cases treated by pinning. The appearances suggest that the pinning is responsible for the necrosis in some cases. Actually in ununited fractures of the femoral neck, not treated by pinning or other internal splinting, the articular surface of the separated head appears to be preserved intact for many years, an example of the value of rest in treatment.

Study of the roentgenographic appearances in these cases of pinning of the femoral neck provides evidence that irrevocable damage may be done to the femoral head by weight-bearing before the fragments have consolidated or reorganized. Since it is impossible to tell by roentgenography or in any other way if, and to what extent, the vascularity of a fragment has been disturbed after pinning, the patient should be kept in bed for from two to three months. At the end of that time roentgenograms will indicate whether there is any disturbance of vascularity and if union is taking place. If the head fragment at that time has the density and appearance of necrosis, one can reckon that it will be three or four years before the necrotic fragment will undergo substitution. Until roentgenograms show that this has occurred, even though they reveal union of the fragments, weight-bearing will result in displacement, deformity, and prolonged disability. Immediate operative measures for removal of the necrotic fragment and ankylosis of the joint would result in a shortened period of invalidism, a factor perhaps of greater importance in adults.

SUMMARY

1. Disturbance of the vascularity of bone by trauma, emboli, in-

flammatory, or neoplastic changes may result in avascular necrosis of the affected bone.

2. Avascular necrosis becomes associated with osteoporosis of the adjacent bone and the phenomena known as osteochondritis, although it is not always a recognizable factor in the latter condition.

3. Roentgenograms may show evidence of disturbance of the vascularity of a fragment of bone within six weeks of the application of the causal factor. If the signs of osteochondritis develop in association with avascular necrosis, the necrotic fragment will be recognizable by its relative density throughout the whole period of reorganization, — for upwards of four years.

4. It is the long period of bone plasticity in osteochondritis (one to four years) to which the clinician should give due attention, for disregard of this is responsible for the deformities caused by stresses and strains on the inadequately immobilized joint surfaces. Avascular necrotic bone undergoing substitution displays a plasticity which persists over a similar period.

5. Osteochondritis presents a characteristic roentgenographic time table. If the affected part is spared from stresses and strains during plasticity, regeneration is perfect.

6. The roentgenographic changes of Legg's disease and those following surgical trauma in reducing congenital dislocation of the femoral head, dislocation of the femoral head, fractures of the femoral neck, and displacement of the femoral diaphysis from its capital epiphysis are not identical; they vary from complete restoration to complete destruction of the joint, although avascular necrosis may occur in many of these conditions.

7. Roentgenograms do show evidence of pathological changes in the metaphysis of the upper femur in some cases before disintegration and displacement produce the lesion known as slipped epiphysis. Due attention to this roentgenographic finding and the prompt institution of protective measures may prevent the displacement and the consequences of avascular necrosis of the epiphysis.

8. Osteochondritis dissecans produces symptoms when the fragment becomes necrotic or displaced; the lesion may be recognized roentgenographically several years before.

9. Temporary retention of calcium by a fragment of bone does not indicate that the fragment is necrotic; it may fuse without any of the secondary changes characteristic of necrotic bone.

10. Avascular necrosis of bone can be detected roentgenographically by the greater density of a fragment which may exhibit friability associated with decalcification of adjacent bone and by the serial roentgenographic changes which show gradual absorption of the dense and apparently structureless fragment. Hypercalcification of bone is not in itself an indication of avascular necrosis.

11. As long as the necrotic bone is present, decalcification and plasticity of adjacent bone will exist; hence, the indication is that necrotic

bone in traumatic cases should be removed as soon as detected, if for any reason the part cannot be efficiently immobilized until complete restoration can be detected roentgenographically.

12. The destructive changes in the hip joint, due to avascular necrosis following internal splintage (pinning, etc.), are worse than after any form of external immobilization. The pin gives a false sense of security, which lessens the period of freedom from weight-bearing; the latter and, possibly, added vascular damage by the pin probably account for these disasters.

13. No sign of avascular necrosis can be detected during the first month after the trauma; this latent period will be extended to many months if the femoral neck is pinned and the limb is allowed to bear weight.

14. The recognition of avascular necrosis and, thereby, prevention of its important complications would be facilitated if, after pinning, the patient rested in bed with the limb immobilized for three months.

15. The clinical signs and symptoms of disease usually disappear (at any rate for a time) long before the plasticity of the bone. Treatment must, therefore, be regulated by the roentgenographic appearances and not by the absence of clinical signs or symptoms. The plasticity of the bone can be judged by the roentgenographic appearances only; therefore, rest of the affected bone should be enforced as long as the roentgenograms suggest plasticity.

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CONGENITAL MALFORMATIONS INDUCED IN RATS BY MATERNAL NUTRITIONAL DEFICIENCY

III. The Malformations of the Extremities

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Congenital malformations are encountered in many fields of medicine. Their repair is associated with great difficulties, and the results of treatment are often unsatisfactory. It is desirable to prevent rather than to treat congenital defects. This desire has kept alive among physicians a definite interest in research work concerned with the etiology of malformations. Apparently a great variety of factors can interfere with the normal development of the embryo. During the last few decades, the discovery of genetic factors leading to malformations has attracted a great deal of attention, while in mammals, at least, the research in the field of environmental teratogenic factors has somewhat lagged behind. However, some important discoveries made in recent years promise to renew the interest in the environmental factors. It is of special interest that, in several instances, a relationship has been found between a faulty maternal diet and anomalies of the offspring. Franke and Tully have described the development of malformations in chick embryos whose mothers were fed grains containing selenium. With the recognition of the importance in nutrition of trace substances, particularly vitamins, it appeared possible that a qualitative maternal dietary deficiency could cause abnormal intra-uterine development of the embryo or foetus. Experiments by Hale; Moore, Huffman, and Duncan; and Andersen pointed to a lack of vitamin A in the maternal diet as a possible cause of various congenital malformations in pigs, calves, and rats. Byerly, Titus, Ellis, and Landauer described micromelia of chick embryos caused by a nutritional deficiency of the laying hens. Warkany and Nelson [8, 9] described the appearance of skeletal abnormalities in the offspring of rats reared on a deficient diet. Since these last experiments were undertaken on a small laboratory animal, it was possible to conduct nutritional as well as morphological studies on a relatively large scale.

EXPERIMENTS

At the age of four weeks, female albino rats of the Sprague-Dawley strain were put on the Steenbock and Black diet No. 2965 (yellow-corn meal 76 per cent., wheat gluten 20 per cent., chemically pure calcium carbonate 3.0 per cent., and chemically pure sodium chloride 1.0 per cent.). This rachitogenic diet was supplemented by viosterol to prevent the devel-

opment of rickets, each female receiving sixty international units of vitamin D every tenth day. This supplemented diet is referred to as Diet I in the following paragraphs. The males used in the breeding experiments were fed an adequate stock diet (yellow-corn meal 57 per cent., whole milk powder 25 per cent., linseed-oil meal 12 per cent., crude casein 3.7 per cent., alfalfa-leaf meal 1.5 per cent., iodized table salt 0.4 per cent., and calcium carbonate 0.4 per cent.).[2] All the rats used in these breeding experiments were externally entirely free of abnormalities. The details of the breeding technique have been described previously [8, 9].

FIG. 1-A
Normal newborn rat.

The females reared on Diet I were retarded in growth and maturation. As a rule they were not mated until they had reached an age of five to six months. At this age successful matings took place frequently, although the pregnancies were not always carried through, a number of females resorbing their foetuses at different stages of development. From fifty-nine females reared and bred on Diet I, 484 offspring were obtained. Of these, 295 were normal; and 189, or 39.05 per cent., were abnormal. It should be pointed out that such a high incidence of abnormalities can be expected as an average only in a large number of litters. Single litters may consist entirely of normal offspring, or entirely of abnormal offspring, or of both normal and abnormal offspring. As a rule, abnormal

FIG. 1-B FIG. 1-C FIG. 1-D

Abnormal newborn rats, showing shortness of mandible, protruding tongue, and abnormalities of the extremities.

offspring were observed more often in second and later litters than in first litters.

Most of the abnormal newborn rats could be recognized as such by external inspection (Figs. 1-B, 1-C, and 1-D). A receding mandible and protruding tongue, as well as various abnormalities of the extremities, could be seen externally. Additional abnormalities were recognized when the newborn rats were cleared and stained according to the method of Schultze-Dawson (Figs. 2-B, 2-C, 2-D, and 2-E). Various degrees of shortening of the corpus mandibulae became noticeable. Fusion of the fifth to the eighth ribs and abnormally premature fusion of the centers of ossification of the sternum were frequently seen in the cleared specimens. Shortening to absence of the radius, ulna, tibia, fibula, metacarpals, and phalanges became recognizable. Thus, it was found that certain bones were often abnormal, while others, like the flat bones of the skull or those of the vertebral column, were not grossly affected.

The incidence of osseous abnormalities found in 100 cleared abnormal specimens can be seen in Table I.

Anatomical details of these osseous defects have been described previously [9]. While the degree and symmetry of abnormalities and the combination of defects varied greatly in the abnormal specimens, a definite pattern was recognizable in the abnormal offspring of the females reared and bred on Diet I. This pattern was called "the pattern of Diet I". It was possible to distinguish clearly from this pattern of malformations other abnormalities which are rarely

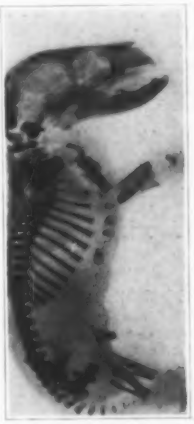

FIG. 2-A

Cleared specimen of normal newborn rat. (*Reproduced by courtesy of the American Journal of Diseases of Children.*[12])

FIG. 2-B FIG. 2-C FIG. 2-D FIG. 2-E

Cleared specimens of abnormal newborn rats, showing shortening of mandible; shortening or absence of radius, ulna, tibia, and fibula; and fusion of ribs. (*Figure 2-C reproduced by courtesy of the American Journal of Diseases of Children.*[12])

TABLE I

FREQUENCY OF OSSEOUS DEFECTS IN 100 CLEARED ABNORMAL SPECIMENS

Tibia	93	Ulna	50
Mandible	80	Humerus	34
Ribs	75	Hindfoot	31
Fibula	63	Maxilla	8
Radius	58	Scapula	6
Hand	54	Clavicle	6
Sternum	52	Femur	1

encountered in this strain of rats, and which originate independently of the diet of the mothers [9].

It seems that the appearance of the malformations of the pattern of Diet I is chiefly a nutritional phenomenon. This opinion is based on the following facts:

1. When females of the same strain were bred on an adequate stock diet, the abnormalities of the pattern of Diet I were not observed in the offspring [9, 10].

2. The addition of 2-per-cent. dried pig liver to Diet I also prevented the appearance of these abnormalities.

3. When females, which had produced abnormal offspring while on Diet I, were given a liver-supplemented diet before they were mated again, the subsequent litters were always found free of the malformations. Other supplements to Diet I, like alfalfa-leaf meal, cod-liver oil, wheat-germ oil, casein, iodine, and manganese did not prevent these abnormalities [12]. Thus it appears that a nutritional factor, deficient in Diet I but present in large amounts in pig liver, is necessary for the normal intra-uterine development of the skeleton of the rat.

FIG. 3-A

Cleared specimen of normal newborn rat.

It is the purpose of this paper to describe in some detail the extremities of the newborn rats, which show the congenital malformations of the pattern of Diet I. Since there exists a great variety of malformations within this pattern, some representative examples

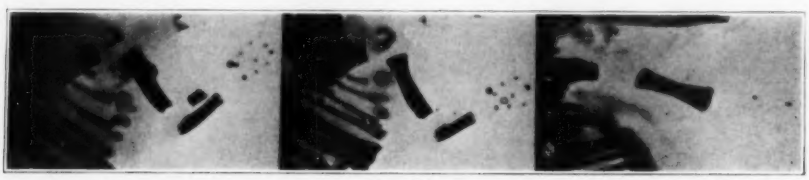

FIG. 3-B FIG. 3-C FIG. 3-D

Cleared specimens of abnormal newborn rats.

Fig. 3-B: The radius and ulna are shortened.

Fig. 3-C: The radius is hardly visible and the ulna is shortened. There is reduction of the skeletal elements of the hands.

Fig. 3-D: The radius and ulna are not visible, and the skeletal elements of the hands are decreased.

will be chosen for anatomical and histological description. While such a description cannot be expected to cover all degrees of malformations, it will permit certain conclusions concerning the foetal stage in which the abnormalities are determined, and the mechanism which underlies their genesis.

FIG. 4-A
Hand of normal newborn rat. (*Reproduced by courtesy of the American Journal of Diseases of Children.*[12])

UPPER EXTREMITY

Figure 1-A represents a normal newborn rat. Figures 1-B, 1-C, and 1-D show abnormal newborn rats, recognizable as such by the short mandibles, protruding tongues, and abnormalities of the extremities. In Figure 1-B the forearm appears slightly reduced in length; the elbow can be seen in this animal. Figures 1-C and 1-D represent a definite form of micromelia, in which the elbow cannot be recognized, and the arm points downward instead of forward. The cleared specimens in Figures 3-B, 3-C, and 3-D show the skeletal background of such anomalies, while Figure 3-A illustrates

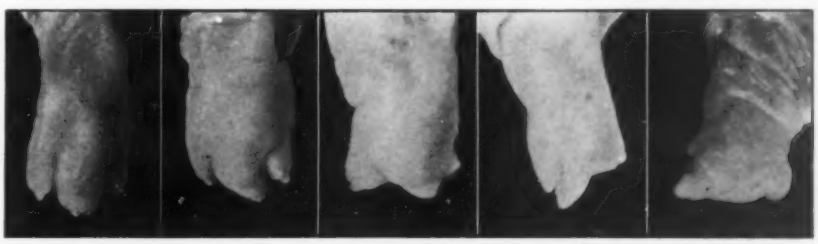

FIG. 4-B FIG. 4-C FIG. 4-D FIG. 4-E FIG. 4-F

Hands of abnormal newborn rats showing various degrees of syndactylism and brachydactylism. (*Figures 4-B, 4-C, 4-D, and 4-E reproduced by courtesy of the American Journal of Diseases of Children.*[12])

the normal skeletal development of a newborn rat. The humerus appears of normal length in the abnormal specimens. The shortening of their upper extremities is not due to any abnormality of this bone. The only deviation from the norm occasionally observed in the humerus is the absence of the deltoid tuberosity as illustrated by Figures 3-C and 3-D. In Figure 3-B the radius and ulna are present, but both bones are reduced to about one-third of their normal length. Figure 3-C shows a short ulna, while the radius is indicated by a tiny center of ossification only. In Figure 3-D neither the radius nor the ulna is visible.

A great variety of abnormalities occurs in the hands of about one half of the abnormal offspring. The hand of the normal newborn rat shows four well-developed fingers and a very small thumb (Fig. 4-A). In the abnormal offspring, different forms of syndactylism and brachydactylism are frequently observed. A fusion of the third and fourth digits leads to the formation of a broad central digit (Figs. 1-B, 1-D, and 4-C). If this

fusion is not complete, the central digit ends in two tips (Fig. 4-B). The fingers deviate sometimes from the long axis of the hand (Figs. 4-C, 4-D, and 4-E). In rare cases the hands are reduced to finlike appendages (Fig. 4-F). The cleared specimens show a variety of patterns in such hands (Figs. 3-B, 3-C, and 3-D), but they do not reveal the underlying cartilaginous structure of the abnormalities, since only ossified tissue is stained and made visible in these preparations. A better understanding of the deformities can be obtained by the histological study of such abnormal hands (Figs. 5-B, 5-C, 5-D, 5-E, and 5-F). Figure 5-A represents a section of the hand of a normal newborn rat. The carpus is made up of well-developed cartilaginous elements, which are separated from each other and from the neighboring structures by regular joint spaces. The metacarpal bones show cartilaginous ends, and centrally located centers of ossification between them. The phalanges which follow distally are chiefly cartilaginous, but centers of ossification can be recognized.

FIG. 5-A

Section of a hand of a normal newborn rat (×8).

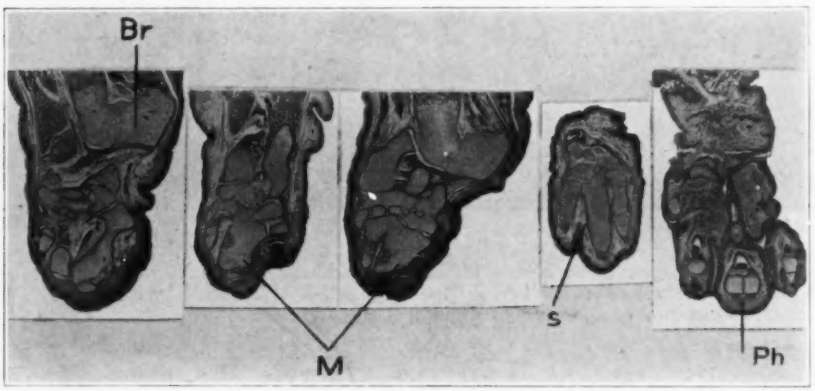

FIG. 5-B FIG. 5-C FIG. 5-D FIG. 5-E FIG. 5-F

Sections of hands of abnormal newborn rats (×8).

Fig. 5-B: Shows cartilaginous bridge (*Br*) between the radius and the ulna.

Fig. 5-C: Shows broad and short metacarpal bone (*M*) (representing the unseparated third and fourth metacarpals), with an eccentric, semicircular center of ossification.

Fig. 5-D: Shows irregular arrangement and fusion of the carpal cartilages, and fusion of the metacarpal bones.

Fig. 5-E: Shows a lack of joint formation between the metacarpal cartilage and the basal phalanx of the central digit (*S*). Ossification is retarded.

Fig. 5-F: The central digit has an incomplete separation of the phalanges in the longitudinal direction (*Ph*).

The sections of the abnormal hands do not represent a picture of the entire hands, because, due to the irregular arrangement of their elements, more or less incomplete sections were obtained. However, a variety of cartilaginous and osseous abnormalities can be seen in Figures 5-B, 5-C, 5-D, 5-E, and 5-F. In Figure 5-B, the joint between the distal ends of

the radius and the ulna has not been formed, and a broad cartilaginous bridge (*Br*) between these two bones can be seen. In Figure 5-C, a short but unusually broad metacarpal bone (*M*) is present, and an eccentric and retarded center of ossification can be noticed in it. Figure 5-D illustrates the irregular arrangement and incomplete separation of the carpal elements. It also shows two incompletely separated metacarpal bones, one of which appears short and broad, and has an eccentric center of ossification. These broad metacarpals (*M* in Figures 5-C and 5-D) represent two fused—or better, not separated—metacarpal bones. In Figure 5-E, a long central cartilaginous structure can be seen. On both sides of this structure the elements of an articular capsule are discernible in a line with the metacarpophalangeal joint of the neighboring finger. However, no joint space has been formed between this central metacarpal and its basic phalanx. They appear fused, and represent a single rod. Figure 5-F shows a broad middle phalanx, and in it two incompletely separated cartilaginous structures. The abnormalities of the digits described in the sections above represent the histological background of the various forms of syndactylism and brachydactylism observed on external inspection. They all go back to a lack of differentiation of the cartilaginous structures into the normal skeletal elements.

LOWER EXTREMITY

In Figure 1-B a definite shortening of the leg can be recognized, and in Figures 1-C and 1-D the lower leg appears so short that the foot seems to be attached to the thigh. This gives the impression that the knee is formed by the thigh and the foot. The impression is not correct, since microscopic examination of such specimens reveals the presence of very reduced cartilaginous structures between the femur and the foot, which represent the abnormal tibia (Fig. 6-D) and fibula. However, the shortness of these structures causes a complete displacement of the foot; the planta pedis, instead of pointing downward, is directed backward and inward. The appearance of abnormal legs of cleared specimens is represented in Figures 2-B, 2-C, 2-D, and 2-E. The femur appears normal in all of the cleared specimens. The tibia is definitely shortened in Figure 2-B. Both the tibia and fibula are curved, the convexity facing backwards. The fibula appears only slightly shortened. In Figure 2-C, the tibia is not visible. In Figure 2-D, a small dot represents the fibula, and in Figure 2-E neither tibia nor fibula is visible. In Figures 2-B, 2-C, and 2-D, the skeleton of the feet appears normal. The shortening of the lower extremity is therefore chiefly due to the abnormalities of the bones of the lower leg. It can be seen from Table I that, in the cleared specimens, the tibia is most often found abnormal. A thorough histological study of this structure has been made [11], and in Figures 6-B, 6-C, and 6-D, three sections of abnormal tibiae are reproduced; Figure 6-A represents a normal tibia for comparison. All the abnormal tibiae are definitely shortened. In Figure 6-B, this shortening is chiefly caused by a

FIG. 6-A

FIG. 6-B

FIG. 6-C

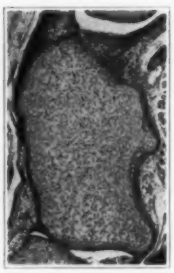

FIG. 6-D

Fig. 6-A: Section of the tibia of a normal newborn rat (× 20).

Figs. 6-B, 6-C, and 6-D: Sections of tibiae of abnormal newborn rats (× 20).

Fig. 6-B: Shows shortening of the metaphysis and cartilaginous islands in the metaphysis. The bone trabeculae converge to a point in the middle of the posterior outline of the tibia.

Fig. 6-C: Shows marked shortening and curving of a tibia composed almost entirely of cartilage. A center of ossification has begun to form in the posterior bulge of this tibia.

Fig. 6-D: Shows a very small, entirely cartilaginous tibia.

reduction of the osseous part of the tibia, while the cartilaginous ends are of normal length. The lines of ossification, which appear straight in the normal tibia, take an irregular course in Figure 6-B. Large cartilaginous areas remain within the metaphysis. The bone trabeculae take an abnormal diagonal course, and converge towards a slightly elevated point in the center of the posterior aspect of the bone. Figure 6-C shows an almost entirely cartilaginous tibia. This cartilage, however, shows definite differentiation, a center of ossification being formed in the bulge on the posterior face of the structure. This bulge is covered by a thin shell of bone, but consists otherwise entirely of swollen cartilage cells. Anterior to these cells lies columnar cartilage with the columns of cells converging

toward the bulge. In Figure 6-D, a very small, entirely cartilaginous tibia is shown.

The hindfeet may also show abnormalities which resemble those described in the hands. The incidence of abnormalities of the hindfeet is lower than that of the hands (Table I).

These experiments and the morphological studies give a certain insight into the genesis of the congenital malformations described. However, many questions concerning the mechanism of the abnormal bone formation remain unanswered at the present time. It may be safely concluded that the abnormal bone development observed dates back to the cartilaginous or precartilaginous stages of the structures involved. This is shown by the abnormal appearance of structures in which ossification has not yet taken place (Figs. 5-B, 5-C, 5-D, 5-E, and 5-F and 6-B, 6-C, and 6-D). The abnormal outline, the abnormal curving, and the abnormal relation between the length and the width of the bones can be seen already in their cartilaginous stage. All the abnormal structures show a delay in ossification. The cartilaginous precursors of the bones exhibit a lack of regular differentiation into the elements of the normal skeleton. Thus it is seen that in abnormal newborn rats, a common cartilaginous bridge may continue to exist between the radius and the ulna (Fig. 5-B); that a cartilaginous phalangeal plate may fail to divide parallel to the long axis into two digits (Figs. 5-C and 5-D), thus leading to syndactylism; or that a phalangeal plate may fail to divide in the transverse direction (Fig. 5-E) and thus fail to form a normal joint. A finger affected in this way will show a reduced number of phalanges and brachydactylism will result. In such abnormal cartilaginous structures, the centers of ossification appear in an eccentric position. This leads to an abnormal arrangement of the bone trabeculae. Projections or islands of cartilage persist in places where bone should be. No explanation is offered at the present time for the fact that certain bones are more often affected than others.

SUMMARY

Congenital malformations, induced in rats by maternal nutritional deficiency, date back to the cartilaginous or precartilaginous stage of the structures affected. The defects of ossification are secondary results, caused by the faulty development of the precursors of the bones.

Many cartilaginous structures show a lack of division in the longitudinal and transverse direction; this leads to a reduction in the number of the skeletal elements, and to syndactylism and brachydactylism in the paws.

The radius, ulna, tibia, and fibula are frequently shortened in the cartilaginous stage. Ossification is delayed and faulty, and eccentric centers of ossification lead to an abnormal arrangement of the bone trabeculae.

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TANGENTIAL OSTEOCHONDRAL FRACTURE OF THE PATELLA *

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Confronted with the presence of a loose body in the knee joint, most of us are prone to make a diagnosis of osteochondritis dissecans.

The purpose in presenting these cases is to delineate the syndrome of osteochondral fracture of the patella, urge its early recognition, and differentiate it clinically and pathologically from the degenerative type of osteochondritis dissecans of the patella, which also results in the formation of free bodies.

This lesion surely is not as uncommon as the literature would seem to suggest. Essentially the story is the following: A child or young adult twists the knee, usually in the extended position. A loud noise, sudden pain, and occasionally a distinct dislocation of the patella laterally ensue. The knee fills with blood. Disability is usually complete. When, in the course of one to three weeks, the swelling begins to subside, and motion is recommended, a free body is found to exist within the joint. If operation is performed early, it will be found that a previously quite normal patella has experienced a purely traumatic avulsion of the cartilage of (usually) its medial inferior quadrant.

If the lesion is not recognized and operation is not performed early, recurrent episodes of free-body impingement will eventually necessitate operation. At this late date, the free body will be indistinguishable from the free body of an idiopathic degenerative osteochondritis dissecans. Its bed will have healed over, and similarly, be little different from the frequently described degenerative lesion.

A survey of the literature for similar or related material indicates that Kroner in 1904 first reported a vertical-frontal fracture of the patella, in which the entire patella was split into two frontal sections. Of particular interest in this case is the evidence that the patella was dislocated laterally, and that the fragment with the deeper cartilaginous surface remained caught laterally by the external condyle of the femur, while the remaining osseous layer of the patella reduced itself. The fracture occurred in a woman, thirty-one years old, while she was running on smooth ground.

In 1921 Villar reported a similar case resulting from a gunshot injury, and called it an oyster-shell fracture.

In 1923 Kleinberg reported a case, more pertinent to this group, in a boy of eighteen years (very similar to Case 2 of the present series), and suggested that a fall on the knee, forcing the patella downward on the femur, could shove or scrape off part of the articular surface. In 1932, he reported a traumatic lateral dislocation of the patella (without fracture)

* Read at the Annual Meeting of The American Orthopaedic Association, Baltimore, Maryland, June 4, 1942.

FIG. 1-A

Case 1. Preoperative roentgenogram. Note the slight irregularity in the contour of the lower third of the articular surface of the patella.

of five days' duration which resisted reduction. At open operation it was found that the medial border of the patella had caught on the femoral condyle. This observation is of interest, and would lend support to Kroner's concept of the mechanogenesis of injury.

Between 1924 and 1928 Krida, Stewart, and Leitloff reported cases of frontal fractures in adults. In 1937 Meekison under the title of "A Hitherto Undescribed Fracture of the Patella" reported in three adults the separation of a circular piece of articular surface of the patella, one and five-tenths to two centimeters in diameter, obviously torn from the medial inferior aspect of the bone. They occurred in consequence of rather severe injuries, and Meekison presumed the mechanism in the main consisted "of a glancing blow on the patella from the inner side and directed obliquely posteriorly, whereby the inferior and medial corner of the articular surface is knocked out, presumably by the lateral condyle of the femur". Only one of the patients was operated upon soon after the injury. In this case there was revealed a rent in the medial expansion of the quadriceps, corroborating the patient's statement which indicated the history of a brief dislocation of the patella. In none of his three cases was he able to reveal evidence of the fracture by roentgenogram.

Chaklin in 1939, in reporting a series of chondropathic changes on the medial side of the lower portion of the patella, which he attributed to injury, mentions briefly one case in which the cartilage of the lateral border of the patella separated from the main mass. As the result of a direct fall, usually, the patella, forced against the femoral condyle by a sudden contraction of the quadriceps, is subjected to stresses sufficient to destroy the cartilage, but insufficient to effect a fracture. The injured cartilage undergoes further degeneration and changes which finally lead to sequestration. This latter view emphasizing degenerative alterations is rather widely held.

CASE REPORTS

CASE 1. R. C. (No. 57761), a schoolboy, aged ten years, was admitted March 14, 1936. Five days previously, the patient, perfectly well, was standing and wrestling with a playmate. Erect, he leaned forward forcibly, when something "broke like a stick" in his right knee. Immediately severe pain, swelling, and complete disability appeared. When the knee was aspirated later in the day, sixty cubic centimeters of pure blood was obtained. Only diffuse tenderness could be made out. The quadriceps could not be actively contracted, and the affected patella was one-half inch lower than the normal left. The roentgenogram, (Fig. 1-A) was read as negative, and a clinical diagnosis of possible rupture of the quadriceps tendon was made.

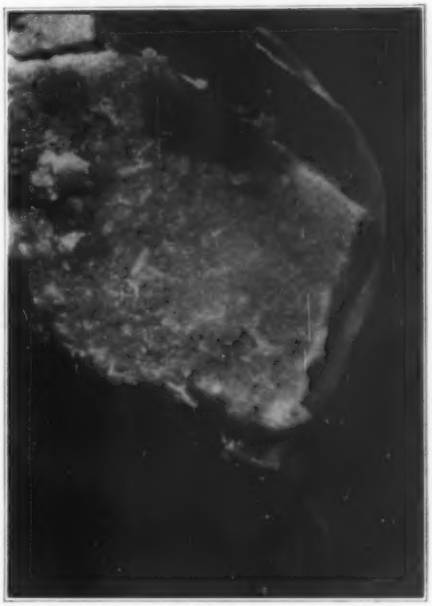

FIG. 1-B

The free body (× 2).

At operation on March 14, 1936, a large amount of blood and clots escaped from a medial incision. A fresh fragment of articular cartilage attached to a thin layer of bone was found loose in the joint. It obviously had been torn from the lateral inferior quadrant of the patellar articular surface, and measured three-quarters of an inch by one-half inch. Visible on the outer portion of the lateral condyle of the femur were a series of fresh fissured lines of a stellate fracture of this condyle. The fragment of patella was removed, and healing was uneventful. In six weeks he was almost symptomless. One year later, the sole finding was some slight atrophy of the thigh. Careful restudy of the preoperative roentgenogram revealed a definite irregularity of the lower third of the articular contour of the patella, corresponding to the area denuded of cartilage.

The pathological examination was made by H. L. Jaffe, M.D.

Microscopic Examination (B-15064): Sections show areas of swelling and degeneration on the superficial surface of the cartilage. In places there are blood clots on the degenerated and damaged cartilage (Fig. 1-B). The subchondral bone is necrotic, and the subchondral marrow spaces show recent hemorrhage.

Diagnosis: Osteochondral fracture of the patella.

The picture here is not like that of the ordinary case of osteochondritis dissecans.

CASE 2. S. S. (No. 213688), a schoolboy, aged sixteen years, was admitted July 17, 1938. Twenty-four hours previously, while standing under a shower, the patient had reached upwards for the knob, and had twisted his left knee forcibly. He was conscious at once of extreme pain, worse on the inner side of the knee. He did not fall. Attempts at motion since then had caused "catching" in the knee.

Examination: The knee was distended and held at 160 degrees, beyond which range passive extension was blocked and painful. Flexion was possible to 100 degrees. Tenderness was present mainly over the medial and lateral borders of the patella. The flexion-abduction-rotation manoeuvre elicited marked pain over the medial aspect of the joint. The roentgenogram (Fig. 2-A) revealed a patellar defect, and the shadow of a corresponding joint body. One hundred and twenty-five cubic centimeters of blood was aspirated. When the patient then actively contracted the quadriceps, pain in the knee was complained of at once.

FIG. 2-A

Case 2. Preoperative roentgenogram showing the free body and apparent defect.

FIG. 2-B

At operation, through a lateral approach, the patellar defect of the upper inner quadrant was visible above the femoral condyle. Two free bodies are to be seen below on the right. The synovial membrane laterally is inflamed. Condylar fissures are distinguishable.

FIG. 2-C

Showing free body and joint surface. Note the cracks and avulsed lateral edge.

FIG. 2-D

Free body. Palisades are visible in the lateral view.

On July 26, 1938, an operation was performed through a lateral incision to expose the lateral femoral condyle; much blood and synovial fluid escaped. The upper inner quadrant of the patella (1 by ¾ by ¼ inch) had been freshly sheared off, and lay in the joint (Fig. 2-B). Its bed was filled with a fresh clot. Study of the fresh scratches on the fragment clearly revealed the tangential direction of the force applied. The outer condyle of the femur also showed evidence of recent trauma, for a thin layer of normal cartilage had been peeled off. Evidence of injury to the synovial membrane over the lateral aspect of the condyle was marked. Another smaller fragment from the patella was also present. The free bodies were removed (Figs. 2-C and 2-D). Convalescence was uneventful, and in eight weeks the patient was quite well. A year later, the knee seemed normal.

FIG. 2-E

Showing splitting and separation of tangential layer of articular cartilage with hemorrhage.

The pathological examination was made by H. L. Jaffe, M.D.

Microscopic Examination (B-25689): Sections show in places splitting and separation of the stripped-back tangential layer of the articular cartilage (Fig. 2-E). There is also focal degeneration of the articular cartilage, reflected in loss in cellularity in these areas. The subchondral bone is necrotic. The free margin of the bone shows splintering of the trabeculae. The subchondral marrow spaces show much free hemorrhage and organization of such hemorrhage.

Diagnosis: Osteochondral fracture of the patella.

FIG. 3-A

Case 3. Preoperative roentgenogram. The flake near the tibial spine indicates the free body.

This is not the pathological picture seen in the ordinary case of osteochondritis dissecans.

CASE 3. Miss A. S. (No. 87848), aged twenty-two years, was admitted February 11, 1941. The patient was well until three weeks previously. While "doing a split", the left knee had been extended posteriorly bearing most of the weight on its medial aspect. She slipped the last half of her descent, heard a click, and "felt the knee dislocate". She was unable to straighten it, but tried. As she straightened it another snap occurred, and the patient almost fainted with the sudden pain. The knee rapidly swelled. She was disabled for two weeks when the swelling subsided. Then she noted a lump which was accessible to palpation.

Examination revealed, essentially, a knee with very little effusion, no tenderness, and a free body which appeared when the patient ascended a step. On the roentgenogram a shell-like shadow suggested it to be of patellar origin (Fig. 3-A).

An operation was performed three and one-half weeks after injury through a medial incision; the synovia was stained throughout by recent hemorrhage. Clots were present and occupied a sharply delimited fresh defect on the medial inferior quadrant of the patella. The lower edge of this defect extended to the insertion of the patellar ligament. In the suprapatellar pouch was found a free body with vertical palisaded walls and sharp contours, corresponding to the defect in every detail. The free body bore the mark of recent indentation (Fig. 3-B). Examination of the femoral condyles revealed an area, three-eighths of an inch by one-half inch, on the most prominent portion of the external condyle where the cartilage was frilled and hanging in shreds. The lines of scratches indicated this area had contacted the patella at the moment of shearing or application of the tangential force which resulted in the avulsion of the cartilage of the patella. The thin layer of bone on the free body corresponded to the linear shadow visible on the roentgenogram. The free body was removed. Convalescence was uneventful, but somewhat prolonged for full motion was not recovered for three months. A year later there were still no symptoms.

FIG. 3-B

The free body, showing the grooved articular surface.

The pathological examination was made by H. L. Jaffe, M.D.

Microscopic Examination (87848): Sections show a fissuring and focal degeneration of the articular cartilage. In places, the subchondral tissue consists of bits of subchondral bone in addition to the calcified zone of the articular cartilage. In the subchondral marrow spaces there is organized connective tissue.

Diagnosis: Osteochondral fracture of the patella.

While there are indications that in this case one could make a diagnosis of osteochondral fracture, rather than straightforward osteochondritis dissecans, one cannot be so dogmatic about it as in the cases of B-25689 and B-15064.

Case 4. M. B. (No. 85151), male, aged nineteen years, was admitted August 27, 1940, with a history of repeated lockings during the previous year. He was well prior to that time when, while practising lifting a 200-pound weight, he twisted his knee. Immediate pain, disability, and swelling appeared, and he consulted a hospital clinic. In two weeks the swelling had subsided. However, ever since then at varying intervals he had experienced "something catching" in the knee. At times he could palpate a "bean" in the joint. Studied at another hospital seven months after the accident, an operation had been advised.

Examination was essentially negative save for atrophy of one-half inch in the right thigh and calf. The patient was admitted, and after four days of observation, the presence of a firm movable body was verified, and an operation was advised. Roentgenograms revealed a roughening of the lower end of the articular surface of the patella.

An operation performed September 4, 1940, revealed the presence of one large and two small bodies lying in an almost completely closed-off compartment of the suprapatellar pouch (Fig. 4). The bodies could be made to slip into the joint from the pouch through a valvelike slit one-half inch long, in the anomalous septum which formed the floor of the pouch. The bodies were smoothed off. The medial inferior quadrant of the patella revealed a sharply circumscribed area, three-quarters of an inch in diameter,

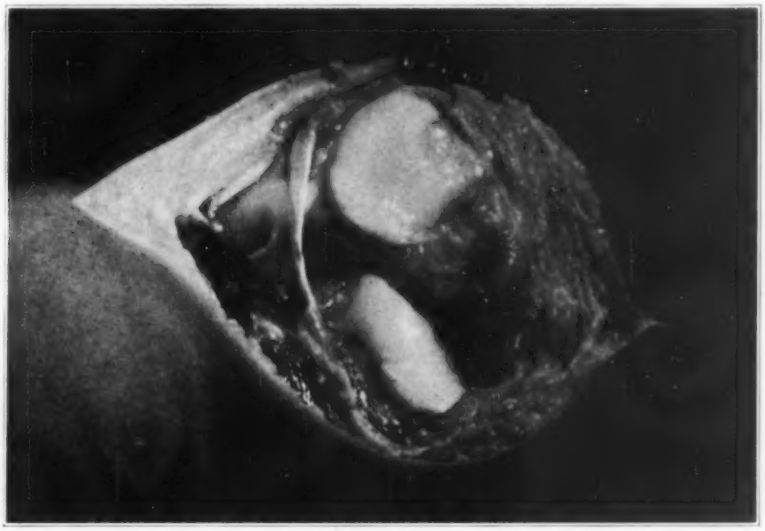

Fig. 4

Case 4. At operation, through a medial approach, the defect in the patella was visible. Septum with hiatus is seen superior to the left. The smoothed-off free body is not visible.

roughly annular in outline, discolored, gray-white against the surrounding normal cartilage. This area was excised, and revealed normally bleeding bone. Convalescence was uneventful; in eight weeks the patient was engaging in full activity.

The pathological examination was made by H. L. Jaffe, M.D.

Microscopic Examination (B-24527): "Sections show the patellar cartilage to be very extensively fibrillized and split. The clefts are lined in many places by flattened cells. The septum is covered by moderately hypertrophied synovial membrane. The joint bodies are composed of calcifying hyaline cartilage, and show some growth through cartilage accretion.

Diagnosis: "(Anomalous synovial septum, quadriceps.) Fibrillization of patellar cartilage; and cartilage bodies in the knee joint."

In three additional cases* the clinical diagnosis of tangential osteochondral fracture was strongly suggested; but in two, operation was refused, and the third was not personally substantiated. These are briefly as follows:

L. P., white, female child, aged nine years, had tripped ten days previously; she had "bruised the knee", and hemarthrosis was demonstrated by aspiration. Upon subsidence of swelling, a free body was palpably present. Operation was refused.

E. S., Negro, male child, aged five years, had been injured four months previously in an automobile collision. Initial swelling, with spontaneous absorption of the effusion, was followed by repeated episodes of knee-catching. A free body was palpable. Operation was refused.

C. L., aged 14 years, had fallen one year previously striking the knee sideways against a stone; hemarthrosis had occurred. The patient was operated upon after many months at a local orthopaedic hospital, and a free body had been removed. Full motion has been slow in returning.

MECHANOGENESIS

In each of the first three patients operated upon soon after the initial accident, definite injury to the lateral femoral condyle was visible, as well as the patellar fracture. In the first, the changes were severe and those of a stellate impacted fracture of the condyle. In the other two, layers of cartilage had been sheared off and hung, still attached, in the midst of adherent blood clots. This strongly suggests the tangential direction and nature of the stresses involved.

The patella momentarily rubs tightly sideways over the outer condyle with sufficient force to score the cartilage of the patella and femur, and leave "glacial grooves" on the patella. Occasionally, probably more often than can be demonstrated, a true dislocation occurs. Then the medial border of the patella catches against the prominent edge of the femoral condyle. As the quadriceps pulls the patella back into line, a chondro-osteal layer is ripped off and left behind (Fig. 1-B), and the condylar synovial membrane locally is markedly traumatized.

In each of these cases, the forces involved were purely muscular and indirect. The lesion, judging from the literature, can also be caused by direct (glancing, tangential) blows. The power of the suddenly contract-

* Since preparation of this article, two more cases in males twelve and thirty-two years of age have been verified operatively.

ing quadriceps is very considerable. In none of the author's cases was there any unusual knock-knee. It has not been possible to reproduce the lesion on the cadaver.

OPERATIVE PATELLAR PATHOLOGY

In patients operated upon immediately or soon after the injury, the knee joint is found distended with hemorrhage. The free body is large, and is particularly characterized by sharp palisade-like edges, where the cartilage has been broken free from its normal continuity. The cartilage is firm, glistening, and obviously normal. However, it is marked by fresh scratches or grooves (Figs. 2-C and 2-D). If the cartilage lies about in the joint, a bleb may form on the surface, for the tangential forces have caused superficial clefts which fill with blood and serum (Fig. 2-E). Microscopic section of such bodies reveals normal live cartilage. The layer of bone which adheres on separation, and is revealed by careful study of the roentgenogram, is usually, but not necessarily, thin. The marrow, early, is normal. The defect is grossly fresh, and is filled with a blood clot.

In patients operated upon even as early as three weeks after the injury, the defect is already healing, while the loose body is beginning to undergo degeneration which will eventually make it indistinguishable from the free body of idiopathic degenerative osteochondritis dissecans.

In patients operated upon a year after injury, as in Case 4, pathologically all that can be said of the free body is that it consists essentially of cartilage, once necrotic and now calcified, slowly growing smooth by accretion. Incidentally in Case 4, the body nestled safely in an anomalous recess of the suprapatellar pouch (Fig. 4) for long periods, emerging through a valvelike slit in the transverse pouch septum from time to time. In the intervals, the patient was symptomless.

It is not intended to suggest that so-called degenerative osteochondritis of the patella of Monroe, of Broca, and of König is not the common delayed cause of free bodies. It is demonstrated, however, that the traumatic immediate production of free bodies from normal cartilage does occur, and constitutes an easily recognizable group if operation is performed early. If operation is performed late, the differentiation is less sure pathologically, and only the clinical story may suggest the true course of events.

In the presence of hemarthrosis, particularly in the young, the patella should be carefully scrutinized for evidence of articular irregularity. A flakelike shadow (Fig. 3-A) in the joint may make the diagnosis fairly certain.

TREATMENT

Operation is indicated for removal of the free body. Prompt removal will minimize further trauma to the joint during the period when diagnosis is more difficult to make, and will curtail the period of recovery and

incapacity. Inspection of the articular patellar surface and particularly of the external condyle of the femur is facilitated by a lateral incision somewhat shorter than the median patellar type usually employed. While the inferior medial quadrant is the commonest site of separation, the entire patellar cartilage must be visualized.

At the time of operation, the presence of a freshly traumatized femoral condyle in one case raised the question of local femoral cartilage excision to anticipate degenerative changes with the ultimate production of a femoral free body. (In the present state of our knowledge, unless the changes are most extensive, these areas had best be left untouched, save for clipping off fresh shreds.)

The walls of the patellar defect were rather perpendicular, and the author thought it advisable to shave the peripheral edges of the defect down to a moderate obliquity. Further free-body formation at the site of patellar defect has so far not been experienced.

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A SUBTROCHANTERIC OSTEOTOMY FOR PELVIC SUPPORT

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Subtrochanteric osteotomies in cases of irreducible congenital dislocation of the hip have become a well-recognized procedure. Designed to obtain a suitable pelvic support, the two methods most generally accepted are the bifurcation operation recommended by Lorenz in 1919, and the low subtrochanteric osteotomy of Schanz described in 1922. The Lorenz operation consists of a subtrochanteric osteotomy at the level of the acetabulum in an oblique direction and the placing of the upper end of the distal fragment into the acetabulum. The Schanz osteotomy is carried out at the level of the tuberosity of the ischium.

That the solution to this problem has not been altogether satisfactory is indicated in a recent article by Milch. His objections to the Lorenz bifurcation are based primarily on the pain and limited range of motion which seem to follow. Milch assumes that the bone spike formed by the upper end of the osteotomized shaft and "directed . . . against the anterolateral wall of the ischium", is the cause of the pain which his patients presented, and that the spike itself "imposes the necessity of greater abduction and the assurance of limitation of motion". He concludes that in obstinate cases, the point of the spike should be resected.

Although Milch's operative technique, as shown in the illustrations included in his article, fails to adhere strictly to the bifurcation procedure as described by Lorenz, it should nevertheless be noted that reports by other authors have been none too satisfactory, and that reports of good results are frequently matched by failures due to pain on weight-bearing and some undue interference with motion [1].

It is not the purpose of this article to discuss the various arguments advanced against the Lorenz bifurcation or the Schanz osteotomy, nor the methods suggested to overcome these difficulties, but rather to present a new and more effective procedure which appears capable of restoring stability to the hip, at the same time ensuring freedom from pain as well as adequate mobility.

In earlier papers [2,3], dealing with the Lorenz bifurcation, the author has repeatedly emphasized that, in cases in which the lesser trochanter is found opposite or near the acetabulum, as in the supracotyloid position, a more effective result might be obtained by displacing the *lesser trochanter* into the acetabulum, and transposing the osteotomized shaft of the femur beneath the lower end of the upper fragment. "The lesser trochanter, because of its round and smooth surface, presents a most suitable object to substitute for the head of the femur, to ensure optimum pelvic support and sufficient hip motion as well."

The initial stimulus for the employment of this procedure was obtained in the observation of a case in which a *spontaneous* pelvic support,

by means of the lesser trochanter, had occurred. In a woman, aged forty-two, with an untreated bilateral congenital dislocation of the hips, roentgenograms revealed that the lesser trochanters on both sides articulated with the corresponding acetabula to form an excellent pelvic support (Fig. 1). She had no complaints whatsoever except some limitation of adduction.

This case suggested the systematic use of the lesser trochanter as a supporting point in all cases of old congenital dislocation of the hip. The method has proved much more successful than the original Lorenz bifurcation and other similar methods. The lesser-trochanter method was later advocated with full acknowledgement of the writer's priority by Kreuz, at the Congress of the International Association of Orthopaedic Surgeons, held in Paris in 1930; and finally adopted by Lance, who considered the displacement of the lesser trochanter into the acetabulum as the only salvation for the Lorenz bifurcation, and the method best capable of effecting rehabilitation of the unstable hip. Lance, however, placed greater emphasis on the adduction of the proximal fragment than on the displacement of the lesser trochanter into the acetabulum, and recommended a special instrument called "*davier-tracteur*" in order to achieve better relation between the proximal fragment and the lateral wall of the pelvis.

FIG. 1

Roentgenogram of a bilateral congenital dislocation of the hip in a woman, aged forty-two years, who never had had any treatment. Spontaneous pelvic support by means of the lesser trochanter had occurred. Both lesser trochanters were hypertrophic and articulated at the site of the acetabulum. Clinically, she had no complaints.

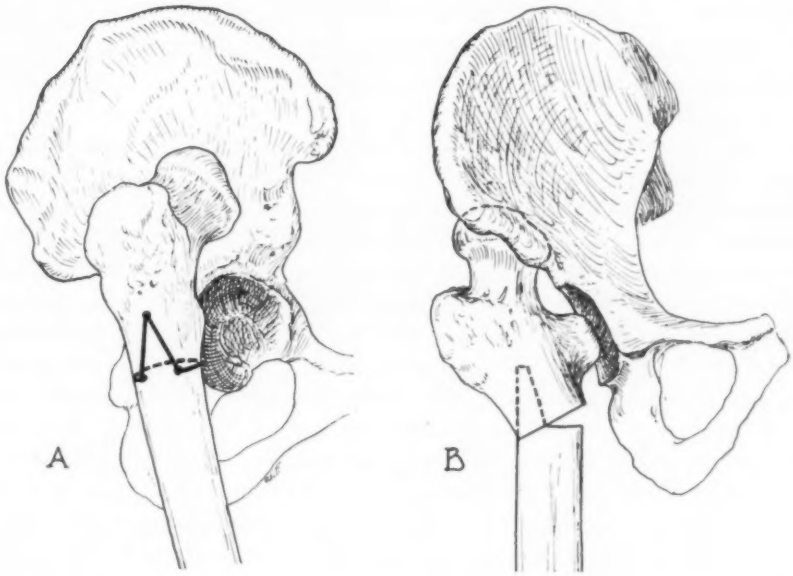

FIG. 2

A: Lateral view of a locking osteotomy performed by forming a triangular plug and slot in the outer surface of the femoral shaft beneath the lesser trochanter.
B: Anterior view shows the divided femur and the lesser trochanter displaced into the acetabulum.

INDICATIONS

It will be appreciated that the indication for any kind of subtrochanteric osteotomy in congenital hip dislocations is dependent upon their irreducibility. In cases in which the head can be reduced, but does not remain in the socket, other operative methods may well be considered,—such as open reduction or shelf operations. For the *irreducible* dislocation, however, the lesser-trochanter method is most suitable, and is especially applicable to cases of anterior, lateral, or intermediate positions (luxatio supracotyloidea and luxatio supracotyloidea et iliaca). In cases such as these, roentgenograms show a well-developed lesser trochanter, usually situated just opposite or near the acetabulum, practically inviting its displacement into the acetabulum. Experience has shown that the lesser trochanter may be used as well in higher positions of the femoral head (luxatio iliaca), after a preliminary period of about two weeks of skeletal traction has drawn the lesser trochanter down to the level of the acetabulum. As a matter of fact, the use of the lesser trochanter is the method applicable in the great majority of irreducible hip dislocations, with the exception of those rather rare cases of a very high iliac position of the head which is so fixed that it cannot be brought down by any means. It is for such cases that the original Lorenz bifurcation or the Shanz osteotomy may be reserved. To avoid any disturbance of growth the operation should not be carried out before the age of fourteen.

OPERATIVE TECHNIQUE

The operation consists of two parts: (1) a locking osteotomy beneath the lesser trochanter; (2) the displacement of the lesser trochanter into the acetabulum.

The patient is placed on the side and fixed in this position by sandbags. Through a longitudinal incision, four or five inches below the greater trochanter, the lateral subtrochanteric aspect of the femur is exposed. The incision is carried down through the periosteum, which is stripped and retracted with the muscles. Following this, a *locking* osteotomy is carried out just below the lesser trochanter. This is done by forming a triangular slot and plug on the outer surface of the femur, to prevent sliding of the fragments and to ensure solid bony union at the site of the osteotomy (Fig. 2).* The entire site of the osteotomy is first outlined with a narrow osteotome. To further facilitate the procedure, three drill holes are placed to mark the corners of the triangle on the outer surface of the femur. Division is then completed by cutting the triangular plug and dividing the inner cortex of the shaft transversely.

FIG. 3

Diagram of the spica cast after the operation, with knee hinges inserted.

After the osteotomy is completed, and while the leg is gently abducted with one hand, the thumb of the other is pressed inward against the plug, as well as against the lower end of the upper fragment. In this manner, the lesser trochanter is directed toward the acetabulum. No slipping is possible, since both fragments are interlocked. The technique is the same in bilateral cases. Recently in order to shorten the period of hospitalization, the entire bilateral operation was completed in one stage, the patient being placed with a sandbag beneath the sacrum, so that both sides were readily approachable.

The postoperative angle of abduction should not exceed 30 to 40 degrees in unilateral cases, and should be limited to 10 or 15 degrees in bilateral cases. In other respects, the position is neutral, except for a slight inward rotation of 10 degrees to compensate for a postoperative tendency toward outward rotation. Since the dislocated head is usually posterior, the osteotomy angle is also directed posteriorly to a slight degree. The position is checked by roentgenograms. The wound is then closed and a long spica applied, extending from the axilla to the toes (Fig. 3). In patients over twenty years of age, preliminary tenotomy of the adductor muscles may be necessary to overcome the contracture frequently associated with old congenital hip dislocations, and

* A mortise type of osteotomy was first recommended by Mommsen in cases of extreme flexion ankylosis of the hip or in severe degrees of coxa vara, in order to establish a hingelike motion at the site of the deformity so as to obtain gradual correction of the deformity after the operation.

to prevent a loss of the abduction angle after the operation. Eight weeks postoperatively, the knee is freed and metal hinges are fixed to both sides of the plaster, so that the joint may be flexed. Walking is gradually resumed with the aid of crutches. As a rule, bony union at the site of osteotomy is sufficiently solid after three months to permit removal of the plaster and weight-bearing without support.

END RESULTS

The lesser-trochanter method has been used in eighteen cases of irreducible congenital dislocation of the hip, among which were four bilateral dislocations. Sixteen of the patients were females and two were males. The age of the patients at operation ranged from fourteen to forty years. The observation time in all but one case was more than five years.

The end results in all cases were entirely satisfactory. The pathological lordosis disappeared, the patients were free from pain, the Trendelenberg sign was negative, and the limp was scarcely noticeable. All patients had adequate motion with the exception of one who had had limited motion before operation (Case 4).

A few illustrative cases follow:

CASE 1. W. S., female, aged thirty-two years, with a congenital dislocation of the right hip, had had a bloodless reduction when she was five and one-half years old. She

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 1. W. S. Congenital dislocation of the right hip (luxatio supracotyloidea) in a woman, aged thirty-two years.

Fig. 4-B: Two years after the locking osteotomy, the lesser trochanter is displaced into the acetabulum. There is good pelvic support and a satisfactory range of motion.

had a definite limp which persisted even after the operation. For the previous year she had had increasing pain in the right hip, especially on walking.

Physical Examination: There was shortening on the right side of one and one-half inches. The trochanter was one inch above Nelaton's line. Abduction was restricted; flexion was possible to 30 degrees; external rotation was free; and internal rotation was restricted. The Trendelenberg sign on the right was positive.

Roentgenographic Examination: The acetabulum was extremely shallow; the femoral head was in the anterior position (luxatio supracotyloidea), and resting in a poorly developed secondary fossa; the lesser trochanter was opposite the acetabulum (Fig. 4-A).

Operation: On March 31, 1932, a locking subtrochanteric osteotomy was performed, and the lesser trochanter was placed in the acetabulum.

Follow-Up Examination: In February 1937, the patient had a painless hip, excellent endurance, and a scarcely perceptible limp. Shortening was compensated for. Flexion and abduction were free, but adduction was slightly restricted. The Trendelenberg sign was negative (Fig. 4-B).

Case 2. F. S., female, aged twenty-eight, had a right congenital dislocation. A reduction had been attempted when she was six months of age, without success. She had always walked poorly, although without pain until the past five years when she had had increasing pain on walking.

Physical Examination: There was shortening on the right of two and one-quarter inches. The greater trochanter was two inches above Nelaton's line. Abduction was restricted; there was flexion to 30 degrees; adduction and external rotation were free; and inward rotation was restricted. The Trendelenberg sign was positive.

Roentgenographic Examination: The head of the femur was in a high iliac position (luxatio iliaca); the lesser trochanter was above the acetabular rim (Fig. 5-A).

Treatment: Because of these findings, skeletal traction by means of a Kirschner wire

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 2. F. S. Congenital dislocation of the right hip (luxatio iliaca) in a woman, aged twenty-eight years.

Fig. 5-B: Eight years after the operation. The lesser trochanter had been drawn down by preliminary skeletal traction, and, after a locking osteotomy, had been displaced into the acetabulum. The functional result was perfect.

FIG. 6-A

Case 3. E. J. Bilateral congenital dislocation in a girl, aged fourteen years (luxatio supracotyloidea et iliaca). The patient complained of severe pain and had marked disability.

FIG. 6-B

Ten years after the operation there is good pelvic support on both sides. The patient is free from pain, walks without limp, and has a full range of motion except for slight limitation of adduction.

Note the increased density of the shaft indicating that weight-bearing takes place in the acetabulum.

through the tibial tubercle was employed for two weeks. The lesser trochanter was then brought down opposite the acetabulum. An operation was performed in May 1924.

Follow-Up Examination: In March 1932, the patient had no complaints, but there was a very slight limp. Abduction was completely free; there was flexion to 60 degrees; and adduction was diminished. The Trendelenberg sign was negative. Roentgenograms showed the lesser trochanter to be placed well within the acetabulum; the shaft of the femur had become sclerosed, indicating adaptation to weight-bearing (Fig. 5-B).

Case 3. E. J., female, aged fourteen, had had a bloodless reduction for bilateral congenital dislocation when she was three years old. She had been in plaster for only six weeks, and had then been cared for by means of braces for a long time. She had had gradually increasing pain on walking.

Physical Examination: The left side appeared shorter, and the left superior spine was one inch higher than the right. Both trochanters were two inches above Nelaton's line. Both hips showed flexion and adduction contractures with corresponding restriction of motion. The Trendelenberg sign was positive bilaterally, but more pronounced on the left.

Fig. 7-A

Case 4. I. W. Congenital dislocation of the right hip in a woman, aged forty years, with marked osteoarthritis in the secondary cavity. There was severe pain and limited motion in all directions.

Roentgenographic Examination: The pelvis inclined to the right. There was bilateral dislocation (luxatio supracotyloidea et iliaca), with marked bilateral anteversion. On the left there was a poorly developed secondary fossa (Fig. 6-A).

Operation was performed on the left hip in November 1925, and on the right hip in February 1926.

Follow-Up Examination: Ten years later there were no complaints. The patient exhibited neither waddle nor limp. Adduction was somewhat restricted, but motion otherwise was completely free. Roentgenograms showed the lesser trochanters to be placed well within the acetabula. The head and neck were atrophic; the diaphysis, however, was markedly sclerosed, indicative of permanent transmission of weight-bearing via the lesser trochanter to the femoral shaft (Fig. 6-B).

Case 4. I. W., female aged forty, had a right congenital dislocation. Bloodless reduction had been performed when she was six years of age. She had always limped, but she had no other complaints. Pain had appeared when she was thirty-five, at first after considerable walking, but later after slight effort.

Physical Examination: There was shortening on the right of two and one-half inches. The trochanter was two inches above Nelaton's line. Motion at the hip was almost completely restricted in all directions. The Trendelenberg sign was positive.

Roentgenographic Examination: Luxatio supracotyloidea. The head of the femur was in a secondary acetabulum, and there was irregularity of the joint space and marked marginal exostoses (osteo-arthritis deformans). (See Figure 7-A.)

Operation: In February 1935, a locking osteotomy with displacement of the lesser trochanter was performed, following preliminary subcutaneous tenotomies of the adductors.

Follow-Up Examination: In January 1937, there were no complaints. The patient was free from pain, and had excellent endurance. There was a very slight limp, and the Trendelenberg sign was negative. Roentgenograms showed good pelvic support by means of the lesser trochanter, and increased sclerosis of the femoral shaft (Fig. 7-B).

DISCUSSION

The method described relies for its success largely upon the fact that a new supporting point is established at a *physiological* site of the pelvis,—that is, the acetabulum. Through this new point of contact, the weight-bearing thrust is shifted from the dislocated and unstable femoral head directly onto the shaft of the femur via the lesser trochanter. The operative technique differs from the typical Lorenz bifurcation in several respects. Whereas, in the latter procedure, the upper end of the *distal* fragment is displaced into the socket; in this method, the lesser trochanter as part of the *proximal* fragment is displaced into the acetabulum. At the same time, the upper end of the osteotomized shaft is placed *under* the proximal fragment. In this manner, the lesser trochanter acts as a hypomochlion in the acetabulum, and no spike is formed and "directed against the anterolateral wall of the ischium" which might give rise to pain and other disturbances.

FIG. 7-B

Two years after the operation there was good pelvic support by the lesser trochanter at the site of the acetabulum. There was limitation of motion, but full relief from pain.

The *adduction* of the proximal fragment is an essential factor, as well as the tension of the pelvitrochanteric muscles which results from the

downward tilt of the greater trochanter. The most significant part of the procedure, however, is the *abduction* of the distal fragment by means of which the acetabulum receives the thrust, even though there is but little left of the original acetabulum. The *postoperative angle* is considerably less than that required in the bifurcation operation,—in unilateral cases no more than 30 to 40 degrees. This amount of abduction in unilateral cases can readily be compensated for by the pelvic tilt. In bilateral cases, however, one must be particularly cautious with the abduction, because of the possible failure to bring the limbs into parallel alignment; therefore, abduction should not be more than 10 to 15 degrees. On the other hand, in bilateral cases the pelvis is checked on both sides by the lesser trochanter in a sort of braking action, and, therefore, less abduction is required than in unilateral cases. Particular difficulties may be experienced in bilateral cases in which the dislocation is unequal,—as, for example, in a case with supracotyloid position on one side and an iliac position on the other. As a rule, the higher side requires more abduction than the lower. In any case, it is the author's opinion that the degree of abduction is the most delicate part of the procedure, and should be carefully calculated before the operation, and checked by roentgenograms before closure.

In all likelihood, the adequate *range of motion* which these patients presented postoperatively was due to the smooth and rounded surface of the supporting point, as well as to the fact that the proximal lever of the system—comprising head, neck, and trochanter—is relatively short. Only in adduction may there be slight limitation; and this offers practically no handicap for the patient. As a matter of fact, the postoperative degree of mobility depends almost entirely on the mobility which was present prior to operation. If the head moved freely before the operation, there should be an almost complete range subsequently. If, however, the head was fixed in a secondary false acetabulum—for example, by osteoarthritis—there will, of course, be marked limitation after the operation, as seen in Case 4.

SUMMARY

The author has found valuable a method of pelvic-support osteotomy, in which, by using a locking subtrochanteric osteotomy and displacing the lesser trochanter into the acetabulum, he has secured good stability and freedom from pain, as well as an adequate range of motion, in cases of irreducible congenital dislocation of the hip. The procedure is indicated in cases of supracotyloid position, but can also be employed in high iliac dislocations after preliminary skeletal traction.

Eighteen patients have been treated by this method, of whom four had bilateral dislocations.

The end results, in the author's experience, are much better than those obtained by other methods.

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METASTATIC MALIGNANCY OF THE SPINE

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In any case of chronic low-back pain, the possibility that this symptom may be due to cancer must always be considered. The following study was undertaken to clarify the subject of metastatic malignancy of the spine and to outline therapy for increasing the span of life and for making the patient more comfortable. The ninety-five cases on which the paper is based were seen at the Lahey Clinic from 1936 to 1940 inclusive. Roentgenographic evidence of spinal metastasis was present in each case.

Table I shows the lesions which were encountered. Allied conditions such as lymphoblastoma have been included in this series because of differential diagnostic interest. As indicated in this table, the types of neoplasm which spread most frequently to the spine have their primary origin in the breast and prostate. Metastases to the spine from other sites are unusual.

Table II comprises all the cases of malignancy seen in the Clinic from 1936 to 1940 inclusive. A comparison of Tables I and II shows that, among 1350 neoplasms of the gastro-intestinal tract, there were but two instances of involvement of the spine,—one from the stomach and one from the rectum. Thyroid metastasis is also relatively uncommon. In 160 cases of thyroid cancer, there were only three instances of metastasis to the spine.

Of the ninety-five patients with spinal metastases, thirty-three were males and sixty-two females. Spinal metastasis was twice as prevalent in females as in males, because of the high incidence of breast carcinoma.

DIAGNOSIS

In the whole group of ninety-five cases, the presenting symptoms were astonishingly variable. While back pain was the most common symptom, other complaints were also listed,—weakness of the legs, retention of urine, paraplegia, hip pain, sciatica, and loss of weight. From a traditional point of view, pain in the back which is severe, constant, and not relieved by recumbency or by salicylates is the pain of cancer. In some cases it is curious to find how extensive a metastatic lesion may be and yet cause only mild pain. Therefore, in the early diagnosis of these lesions, it is important that roentgenograms of the spine be taken even in the case of mild back pain. They should, of course, always be taken when there is a history of previous malignancy or where there are any other signs or symptoms suggestive of cancer.

In some cases a clinical diagnosis of metastatic carcinoma is justified, even if it is not borne out by roentgenograms. In certain patients a spinal metastasis may be suspected, but the roentgenograms are found to

TABLE I

CASES OF METASTATIC MALIGNANCY OF THE SPINE SEEN AT THE LAHEY CLINIC FROM 1936 TO 1940 INCLUSIVE

Primary Lesion	No. of Cases
Carcinoma of breast	42
Carcinoma, primary site unknown	15
Carcinoma of prostate	11
Lymphoblastoma (Hodgkin's)	7
Carcinoma of thyroid	3
Plasma-cell myeloma	2
Adenocarcinoma of fundus of uterus	2
Carcinoma of bladder	2
Fibrosarcoma of left-shoulder region	1
Carcinoma of stomach	1
Carcinoma of rectum	1
Liposarcoma of bone	1
Carcinoma of renal pelvis	1
Sarcoma, undifferentiated	1
Adenocarcinoma of body of pancreas	1
Primary carcinoma of lung	1
Lymphosarcoma	1
Epidermoid carcinoma of lip	1
Multiple myeloma	1
Total	95

be negative. However, roentgenograms taken a few weeks or months later may prove to be positive. The author believes that these patients should be treated by roentgenotherapy even before the roentgenographic signs have appeared. At autopsy, spinal metastases are usually more extensive and involve more vertebrae than the x-ray findings would lead one to believe. It is an accepted fact that, in the early stages, spinal metastases are very frequently confused with arthritis.

It has been argued that the early diagnosis of spinal metastasis is not important, because of the incurability of the disease. From the point of view of the patient's comfort, however, it is invaluable, because the sooner the diagnosis is made, the sooner measures may be adopted to lessen the suffering. Moreover, in some cases roentgenotherapy causes the lesion to

TABLE II

TOTAL CASES OF MALIGNANCY SEEN AT THE LAHEY CLINIC FROM 1936 TO 1940 INCLUSIVE

Site of Lesion	No. of Cases
Stomach and gastro-intestinal tract	1350
Breast	326
Thyroid	160
Prostate	140
Throughout body	91
Total	2067

FIG. 1

Widespread osteoblastic pelvic metastases typical of prostatic carcinoma, in a male, sixty-five years old, whose presenting complaint was sciatic pain. Partial relief of pain by roentgenotherapy and cobra venom was secured.

regress or it retards the rate of growth, thus preventing compression of the spine and paraplegia.

In many of the cases in the author's series, the diagnosis was not proved by microscopic section. For example, in the case of an elderly male with a large, stony hard prostate and osteoplastic metastases in the pelvis and spine, a diagnosis of carcinoma of the prostate with metastases is justified without section of the prostate gland. Spinal metastases do not lend themselves to biopsy, so that it must be presumed, for example, that an osteolytic lesion of the spine, occurring after carcinoma of the breast, comes from the breast, unless there is contrary proof in the autopsy findings.

The differentiation of tuberculosis of the spine and spinal metastasis is a diagnostic problem. Also, primary sarcoma of the spine may simulate Pott's disease. In tuberculosis, the classic thinning of the intervertebral disc, the symmetrical abscess shadows, and the calcification within the abscess help to distinguish it from a tumor. In recent years tuberculosis of the spine has become infrequent; therefore, this differential problem is not so often encountered.

Bone cysts and giant-cell tumors are very rare in the spine, but they may produce an osteolytic appearance in the vertebral bodies. Repeated roentgenograms over a considerable period are helpful in making the

diagnosis. The small, rounded, osteolytic areas of multiple myeloma simulate malignant metastases. The characteristic roentgenographic appearance of the skull helps in the diagnosis of multiple myeloma, which may be substantiated by sternal puncture.

One of the very interesting cases in the author's series—that of carcinoma of the body of the pancreas, which metastasized to the lumbar spine—was illustrative of the difficulty in the diagnosis of this lesion. The primary neoplasm was in the silent area of the pancreas, and the patient had no gastro-intestinal symptoms and no jaundice. The metastatic lesion in the lumbar spine produced the first symptoms. In spinal metastasis, when the primary growth is not evident, carcinoma of the body of the pancreas must be considered, as pointed out by Bartels. Thus, in cases with severe thoracolumbar pain, accompanied by loss of weight and negative roentgenographic findings, this site of carcinoma should be considered even without bone metastasis.

METASTATIC CARCINOMA OF THE PROSTATE

Carcinoma of the prostate is the most frequent cause of metastatic malignancy of the spine in the male (Fig. 1), and our findings agree with those of Marks that metastasis is even more common in the pelvic bones.

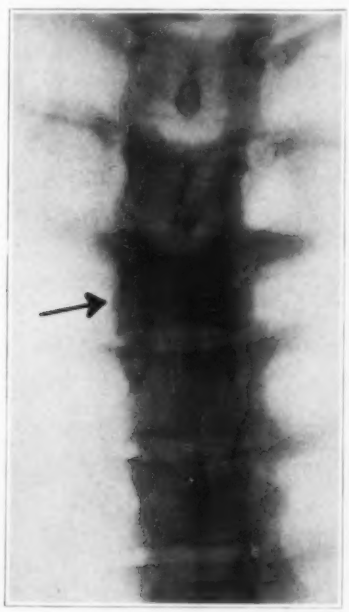

FIG. 2

FIG. 3

Fig. 2: Osteoblastic metastasis involving the fourth thoracic vertebra in a female, thirty-nine years old, with carcinoma simplex of the breast. Onset of back pain occurred one month after radical mastectomy. Roentgenotherapy relieved the back pain. In a later stage the patient received cobra venom.

Fig. 3: Partial collapse of body and destruction of right pedicle of eleventh thoracic vertebra and destruction of left twelfth rib. Back pain was the presenting complaint, the breast carcinoma being unnoticed by the patient.

Prostatic metastases are so typical in their location and roentgenographic appearance that Marks feels that a metastatic lesion of the osteoblastic and mixed types involving the pelvis and lumbar spine in a man is in all probability due to carcinoma of the prostate. Simpson has described extensive pelvic metastases from prostatic carcinoma without bone changes, and he believes that the diagnosis of prostatic metastasis can and should be made without roentgenographic evidence. If the bones of all patients with prostatic carcinoma were carefully examined at autopsy, the incidence of prostatic metastases would certainly be considerably higher than it is at present. These prostatic metastases, while usually characteristic, may simulate Pott's disease. Of all the spinal metastases, the prostatic are the most typical in their roentgenographic appearance. They are usually of the mixed type, being both osteoblastic and osteolytic.

Prostatic metastases may show x-ray evidence of healing after a course of roentgenotherapy. Some healing by x-ray was seen in a case of a male, seventy-five years old, who had sixty-three roentgen treatments and lived for twenty-seven months.

Huggins, Stevens, and Hodges have reported appreciable clinical improvement from orchectomy in fifteen out of twenty-one cases of advanced prostatic carcinoma. A case so treated at this Clinic was a male of seventy-one with carcinoma of the prostate and diffuse bone metastases,

FIG. 4

Metastases from carcinoma of the breast. Partial destruction of the third and fourth ribs posteriorly.

severe back pain, and an acid phosphatase of 1.67 units. Bilateral orchectomy was performed. One week later the acid phosphatase had fallen to 0.43 units. Three months after operation the prostate felt normal in size. The relief of back pain and improvement in general health were striking.

METASTATIC CARCINOMA OF THE BREAST

Roentgenograms show that metastases from the breast are more commonly osteolytic in nature, but they may be osteoblastic (Figs. 2, 5, and 6), osteolytic (Figs. 3 and 4), or both, in the same patient. Metastasis is common in the sacro-iliac region, and frequently causes sciatica.

Carter and Leddy believe that roentgen treatment of vertebral metastases from the breast helps the pain, but they doubt that this treatment is valuable in checking the progress of the metastasis. Pfahler has reported four cases of metastatic carcinoma of the spine in which x-rays demonstrated definite healing, but the writer believes that metastatic carcinoma is generally a local manifestation of a general carcinomatosis and, therefore, only local results and prolongation of life may be expected.

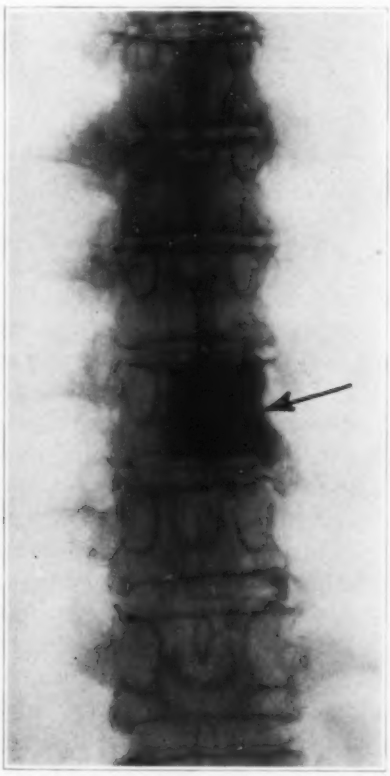

FIG. 5

Very dense osteoblastic metastasis in ninth thoracic vertebral body from carcinoma of breast in a female, sixty-two years old. Back symptoms appeared seven years after radical mastectomy.

Of the group of forty-two cases of carcinoma of the female mammary gland with metastasis to the spine, the youngest patient was twenty years old. The oldest was a woman, aged sixty-eight years, who had a bilateral mastectomy because of carcinoma simplex. During her convalescence, a compression of the second thoracic vertebra was discovered. Roentgenotherapy relieved the back pain.

Five patients came to the Clinic with back pain as the presenting and original symptom, no breast mass ever having been noted previously. Six other patients entered with two complaints,—a lump in the breast and back pain. In another case, spinal metastasis which was not causing symptoms was discovered by routine x-ray examination. Thus is illustrated the value of routine roentgenograms of the spine in all cases of carcinoma of the breast (Fig. 6), as pointed out by Carter. In the remaining thirty cases, the spinal metastasis was found in the roentgenogram from one month to twenty years after mastectomy

FIG. 6

Osteoblastic type of metastasis from breast at sacro-iliac joint. The patient had a "lump in the breast" for six months before coming to the Clinic for "sacro-iliac" trouble. This demonstrates the importance of having x-rays in cases of back pain.

for cancer of the breast. In these thirty cases, two and a half years was the average time elapsing between mastectomy and evidence of metastasis in the roentgenograms of the spine. One woman had had a radical mastectomy of one breast ten years, and of the other breast twenty years, before roentgenographic examination of the spine. This is the longest time to elapse between removal of the breast and discovery by x-ray of the spinal metastasis. In twenty-two of the forty-two cases with spinal metastasis from the breast, mastectomy had been done at the Lahey Clinic. In every case, involvement of lymph nodes was found by the pathologist. In four cases the disease was so far advanced when the patient was first seen that simple excision of the breast was done rather than radical mastectomy.

Thirty-two patients with spinal metastasis from the breast were followed. Three are in fairly good health. One of the three has lived for four years, although the laminae and the body of the fourth lumbar vertebra have been involved. She has been treated by roentgenotherapy only, and this destructive lesion has apparently been arrested for four years.

Of the other twenty-nine patients, six are obviously dying and the twenty-three who have died, lived from one month to four years after the spinal metastasis had been diagnosed by roentgenographic examination,—an average of only eleven months. Thus, life expectancy in a case of carcinoma of the breast with spinal metastasis is very short indeed.

LYMPHOBLASTOMA

The lymphoblastoma group (Hodgkin's disease, Figs. 7 and 8) were included in this series because of the importance of considering these cases in the differential diagnosis of destructive lesions of the spine. Hodgkin's disease causes destructive lesions of the spine which cannot be differentiated by the x-ray appearance from other spinal metastases. These lesions are sensitive to roentgenotherapy and usually do not cause much pain. In Goldman's series of 212 cases of Hodgkin's disease, bone involvement was noted in 6 per cent., the spine being the site most frequently affected.

FIG. 7

FIG. 8

Fig. 7: Vertebral collapse (eleventh thoracic) due to Hodgkin's disease, as proved by autopsy.

Fig. 8: Scirrhous lymphoblastoma (Hodgkin's) involving the anterosuperior portion of the fourth lumbar vertebral body. This lesion was treated by roentgenotherapy and checked by x-rays over a period of eighteen months. There was no definite enlargement during the period of observation.

The seven patients in our series with bone changes in the spine from lymphoblastoma were from twenty-nine to sixty-eight years old. In two of these patients paraplegia developed because of soft-tissue encroachment upon the spinal cord, and laminectomy was done. Four of the patients are now living, having been under treatment for two years, and three are dead. Two died within a year, and the third died after three years. The latter patient had fifty-four roentgenotherapy exposures in all, and the lumbar-spine lesion showed some evidence of healing, although after two years of treatment a new bone lesion developed in a lumbar vertebra above the original site.

Roentgenotherapy can be relied upon to decrease the size of the soft-tissue masses.

OTHER SPINAL METASTASES

There were three cases of carcinoma of the thyroid (Figs. 9-A and 9-B) with metastasis to the spine in the series of 160 thyroid carcinomata. These three patients died within two years. In fifteen cases, the primary site of the spinal metastasis was unknown, and in all of these the metastases were osteolytic in type (Fig. 10).

Chordotomy was performed for intractable pain in one of the cases in which

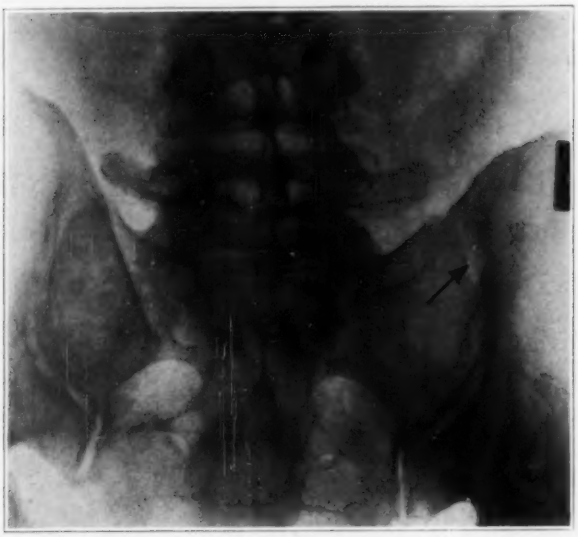

FIG. 9-A

FIG. 9-A

Growth of a metastasis. Carcinoma of the thyroid in a male, forty-five years old. The patient had one week of pain in the left "sacro-iliac region," and the metastasis was missed clinically and roentgenographically until three weeks later (Fig. 9-B).

FIG. 9-B

Growth of a metastasis. Same patient as in Fig. 9-A, three weeks later, with extensive destruction of left posterior ilium, metastasizing from carcinoma of thyroid.

spinal metastasis followed adenocarcinoma of the fundus of the uterus (Figs. 11-A and 11-B), and in one case of carcinoma of the rectum.

Paraplegia occurred in the cases of liposarcoma of the spine, undifferentiated sarcoma, and lymphosarcoma, and laminectomy was performed in these cases.

A metastasis in the second lumbar vertebra arose from a primary carcinoma of the body of the pancreas.

An epidermoid carcinoma of the lip metastasized to the left sacro-iliac region and sacrum in a fifty-six-year-old pipe smoker (Fig. 12).

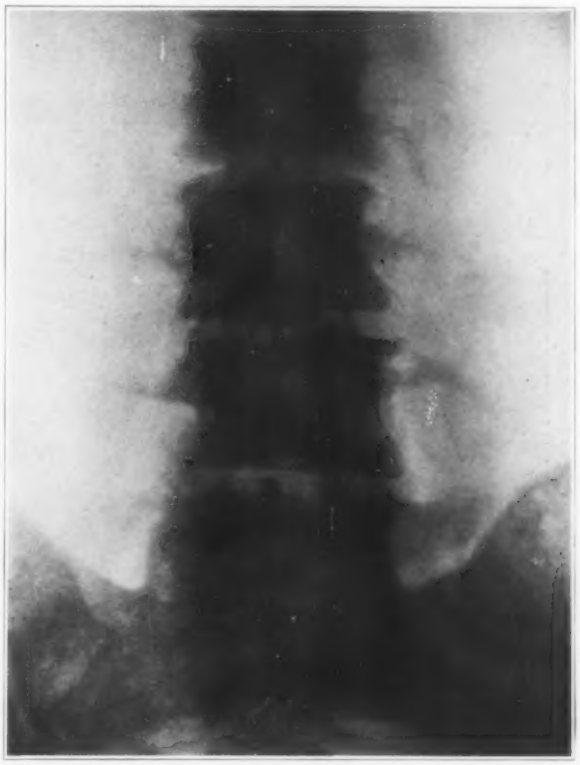

FIG. 10

Widespread carcinomatous metastases in a female, fifty-two years old. Primary site was unknown. Fourteen other patients had spinal metastases from an unidentified primary source, and all these metastases were osteolytic in type.

THERAPY

Our chief weapons in treatment are roentgenotherapy, opiates, cobra venom, braces, subarachnoid injection of alcohol, chordotomy, and orchectomy. In the early stages much can be accomplished by the use of salicylates and codeine, so that it is usually unnecessary to give the patient opiates at the time of diagnosis. From a diagnostic viewpoint, a patient with severe pain thought to be due to arthritis, who does not respond to bed rest and salicylates, usually has a malignancy. Thus, bed rest and salicylates are of value in making a differential diagnosis.

Roentgenotherapy: There is considerable individual variation in the therapeutic results of the x-ray, and it cannot be said that roentgenotherapy is more efficacious in relieving pain in one type of metastasis to the spine than in another.

Opiates: From our clinical experience, dilaudid is favored over morphine, because it gives rise to less nausea, vomiting, and constipation. Tablets of one-twenty-fourth grain are commonly used.

Cobra Venom: Cobra venom has been used to supplant opiates. Usu-

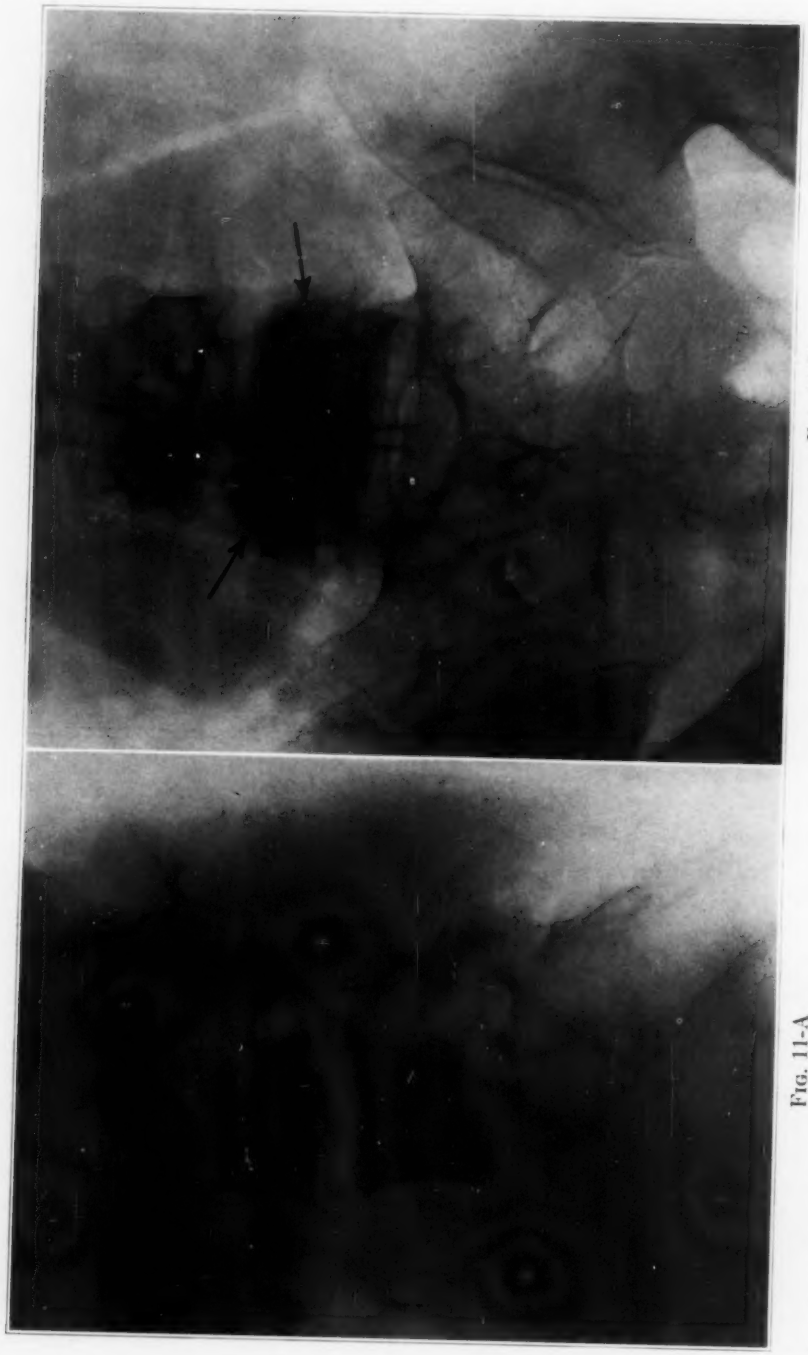

FIG. 11-A

FIG. 11-B

Osteoblastic metastasis involving fifth lumbar vertebra. Hysterectomy had been done for adenocarcinoma of uterus nineteen years before.

FIG. 12

Localized area of destruction involving left sacro-iliac joint. Low-back pain began two weeks after excision of epidermoid carcinoma of lip in a male pipe smoker.

ally one ampule is given daily for from five to ten days. We have not been able to substitute it for morphine in severely painful cases. However, in those cases in which it has been used no untoward effects have been noted. It is the consensus of those who have used it at this Clinic that it fails in most cases, but that it is worth a trial because of the relief which it may produce in isolated cases without the depression of morphine.

Braces: In several cases of metastatic malignancy of the spine the patients were comfortable while recumbent, but, upon getting up, the pain became very severe. In this type of case, especially if roentgenographic examination reveals compression, a brace may be very useful in relieving the pain. We have used the Taylor type,—a long back brace with two vertical metal uprights.

Subarachnoid Injection of Alcohol: The author believes that the neurosurgical measures for the relief of patients with cancer have not been given enough prominence. In individuals whose span of life promises to be short, subarachnoid injection of alcohol frequently relieves sciatica and other lower-extremity and low-back pain. It is useful as well in cancer of the bladder, prostate, rectum, and female pelvis.

One of the unfortunate features of the injection of alcohol intraspinally is that a certain percentage of the patients so treated will have permanent motor weakness of the lower extremities, and also will have loss of bladder control, as well as paraesthesias.

Dogliotti, of Turin, introduced this therapy of blocking the sensory pathways in 1930. Poppen, of the Lahey Clinic, found that in eighty-two

cases, 68 per cent. of the patients were felt to have satisfactory results after the injections. Peyton concluded that a sufficient proportion of patients were benefited to justify the small risk of serious injury to the spinal cord, provided the procedure was limited to the treatment of intractable pain in malignant disease of hopeless prognosis. Russell presented eighteen patients treated by this method, and noted that the injection often relieved the pain of malignant disease.

Subarachnoid injection of alcohol was used in ten cases in the author's series. In the majority of these cases, the metastases were in the fifth lumbar vertebra or in the sacrum. Three patients had complete relief of pain, five had incomplete or transient relief, and two had no relief at all.

Chordotomy: For patients who have a reasonable life expectancy, a major operation such as chordotomy is well worth while. Chordotomy consists in the division of the anterolateral spinothalamic tract and interrupts both the somatic sensory and autonomic sensory pathways. Chordotomy gives more certain relief of pain than subarachnoid injection of alcohol with fewer untoward effects and is, therefore, the preferable procedure unless the patient is unable to undergo a major surgical operation, or the expectation of life is short. Spiller and Martin, in 1912, reported a case of bilateral chordotomy. Since then many other surgeons have reported their results; among these are Horrax, Grant, and Peet.

In our series, three patients who had chordotomy were relieved of pain. It is the author's belief that the neurosurgeon should be called upon more frequently to use this means of pain relief for the cancer patient.

Posterior rhizotomy was used before chordotomy and was given a thorough trial, but it fell into disrepute because of incomplete relief of pain, due to the marked sensory overlap.

Orchectomy: Striking clinical improvement has been noted in advanced cases of prostatic carcinoma treated by orchectomy. Back pain has been relieved, and this reduction of pain comes on very soon after this operation. It is, however, still too early to report end results of this form of therapy in cases of carcinoma of the prostate.

CONCLUSIONS

1. Roentgenograms of the spine should be taken in all cases of persistent back pain, even when symptoms are mild. If the clinical diagnosis of spinal metastasis is made, roentgenotherapy should be employed, even if roentgenograms are negative.

2. Roentgenotherapy is the most valuable means at our disposal for relief of pain in metastatic malignancy of the spine.

3. The results achieved with cobra venom have been disappointing.

4. For intractable pain in the low back, lower extremities, and pelvis, subarachnoid injection of alcohol is useful, although there is the risk of injury to the spinal cord.

5. Chordotomy is the method of choice for patients whose general condition and prognosis for length of life warrant a surgical procedure.

The results are more certain and satisfactory than those obtained by subarachnoid injection of alcohol.

6. Orchectomy is of value in carcinoma of the prostate because of the clinical improvement in cases so treated. It is as yet too early to report the end results of this treatment.

7. Salicylates and codeine were used in the earlier stages, and dilaudid was preferred in the later stages for the control of pain. Chronic back pain unrelieved by recumbency, salicylates, and codeine is usually the pain of cancer.

8. Braces help to relieve back pain in some patients with vertebral compression.

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CYSTIC MYXOMATOUS TUMORS ABOUT THE KNEE: THEIR RELATION TO CYSTS OF THE MENISCI *

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The title of this paper was prompted by the observation of a small group of patients who had been suffering from myxomatous tumors about the knee joint for a period of several years. The authors do not believe that this type of lesion is common. The true etiology of the lesion has aroused their interest, and for that reason four cases will be presented for consideration.

REPORT OF CASES

CASE 1. A woman, forty-five years old, had noticed a mass about the right knee for six months. On physical examination, a small mass was noted on the medial side of the patellar tendon, described as a "ganglion-like cyst or fibroma". An operation was performed, and what was described as a "cartilaginous and myxomatous tumor, three by two centimeters in size" was removed from the anterior border of the medial meniscus. The convalescence of the patient was uneventful, and two years later results of examination of the knee were negative.

CASE 2. The patient was a man, fifty-five years old. Twenty years previous to his admission to the Clinic, he had slipped and injured his right knee. Two years after that, he had first noticed a small, hard non-tender tumor situated beneath the patella. This had gradually increased in size up to the time of the patient's admission. On examination, he presented a large tumor of the anterolateral region of the knee; it was multilocular and firm. In the roentgenographic diagnosis, a large, soft-tissue tumor, not involving the bone, was described on the lateral aspect of the right knee (Fig. 1). At operation, a mass the size of an orange, filled with gelatinous material, was removed from the anterolateral surface of the patella, and a large lobulated mass was removed from beneath the patellar tendon. It extended along the lateral capsule of the joint. There was apparent involvement of the lateral meniscus at one point. Eighteen months later, the knee was reported as being "very satisfactory except for slight stiffness".

CASE 3. The patient was a man, twenty-eight years old. Five years previous to his admission to the Clinic, he had noted a small "bony" outgrowth over the lateral aspect of the left tibia. Locking of the knee had been noted on occasions during the two years prior to his admission to the Clinic. On examination, a swelling was found to be situated along the outer border of the knee joint, localized about the tuberosity of the tibia beneath the attachment of the iliotibial band. At operation a multilocular cystic mass was found to be attached to the lateral meniscus. The cystic mass was two and five-tenths by one by one centimeters in measurement, and the meniscus, three by one by one centimeters. The mass, together with the meniscus, was removed.

CASE 4. A man, forty-eight years old, was admitted to the Clinic. He stated that eight years previously he had "snapped" the left knee. This had been followed by pain

* Read at the Annual Meeting of The American Orthopaedic Association, Toronto, Ontario, Canada, June 12, 1941.

and swelling, and a slowly growing tumor had developed on the inner aspect of the knee. More rapid growth of the tumor had been noted for six months. Constant pain was present, and was worse on sitting and after the patient went to bed at night. A tumor the size of an egg was found at the upper end of the tibia on the medial side of the joint. This was slightly fluctuant, semi-elastic, and felt like a bursa filled with jelly. There was evidence of increased bone formation and traumatic arthritis (Fig. 2-A). The knee could not be fully extended. At operation, a cyst two and one-half inches (about six centimeters) in diameter was found. It was filled with a jelly-like substance. The tuberosity of the tibia was chiseled off where it was hypertrophied (Fig. 2-B), and the same type of cystic mass was found within the tuberosity. At the time of the operation, the authors noted that the lesion probably was a primary cyst of the meniscus, and that the change within the bone was more like pressure erosion than like any tumor of the bone. Two and one-half years later, the patient was said by his physician to have no difficulty with the knee, except slight limitation of movement.

The impression at the time these patients were seen was that the condition present represented unusual developments from cystic menisci. For this reason, the records concerning cysts of the menisci that had been seen at the Mayo Clinic were reviewed. There were seven cases in which the diagnosis seemed definitely to be "cystic semilunar cartilage". In four of these cases, the condition arose in the lateral meniscus and in three it arose in the medial meniscus. This group did not include the four cases here presented. Also reviewed were four cases of what apparently were Baker's cyst of the popliteal space, in which the cystic content was gelatinous material instead of fluid. Only those cases of Baker's cyst with solid mucinous contents were reviewed.

Two other cases of apparent cystic tumor about the knee were included in the group for pathological study.

PATHOLOGICAL ASPECTS

Study was made of the tissue obtained in all these cases to determine, if possible, the pathogenesis of cystic changes involving the menisci, and to ascertain the differential points between the diagnosis of such lesions and of other cystic myxomatous lesions of the knee joint. To this end, "normal" menisci, obtained from patients who had undergone amputation for conditions such as diabetic gangrene, Buerger's disease, and others were studied. In no instance was any demonstrable lesion present in the knee. In the group of "surgical knees", so to speak, from which tissue was removed for therapeutic purposes, this tissue had been labeled "cyst", "myxoma with cyst", "hemorrhage with cyst", "Baker's cyst", "semilunar cartilage cysts", and the like. In all these cases the pathological material was carefully studied grossly, and interesting specimens were photographed or drawn to scale. Particular attention was paid to cysts, and whenever they were found, sections were taken through their walls. Myxomatous masses also were carefully sectioned, and, like the walls of the cysts, were placed in a fresh 10-per-cent. solution of formaldehyde. In seven instances it was possible to identify the meniscus, and from each cartilage multiple blocks were cut and similarly treated. From these formalinized blocks, sections were cut at seven microns, and

FIG. 1

Case 2. October 17, 1939, showing swelling of the soft parts about the lateral side of the knee joint.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 4. February 8, 1937, showing the condition before operation. Note the extensive hypertrophic changes about the medial portion of the tuberosity of the tibia.
Fig. 2-B: May 9, 1937, the same knee after operation, showing the amount of bone which had been removed.

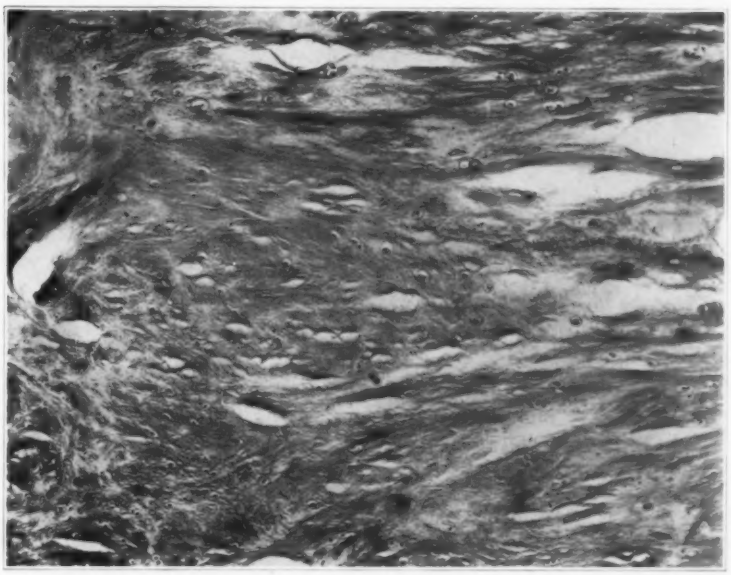

FIG. 3

Photomicrograph (×80) of a normal meniscus. Note the rather acellular fibrocartilaginous composition. The small clefts are artefactual. Hemotoxylin and eosin stains were used.

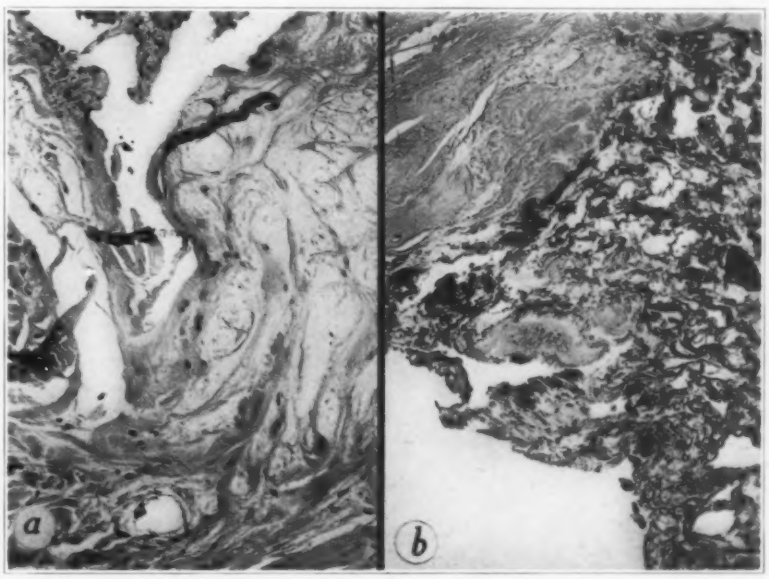

FIG. 4-A FIG. 4-B

Fig. 4-A: Photomicrograph (×80) of a cystic meniscus in the early stage. Compare the myxomatous degeneration and cleft formation with Fig. 3. Hematoxylin and eosin stains were used.

Fig. 4-B: Photomicrograph (×80) of a cystic meniscus. Note the degeneration and actual necrosis of the cartilage. Beginning cyst formation and early fibrosis can be seen. Hematoxylin and eosin stains were used.

stained routinely with hematoxylin and eosin, van Gieson's stain, Galantha's stain for mucus, and, in several instances, Weigert's stain for elastic tissue. In all, about 200 microscopic sections were made available for study.

Gross Examination

From the standpoint of gross inspection, the normal meniscus appeared as a glistening, bluish-white structure, averaging four by one by eight centimeters. The consistency was firm, with a moderate degree of elasticity. Surfaces made by transection were roughly triangular, grayish-white, and homogeneously firm in texture. Cystic areas and zones of softening were not observed.

In the pathological series, cases in which tissue had been labeled "cyst of the semilunar cartilages" appeared to justify such a descriptive designation. In each instance a portion, large or small, of the involved structure appeared to be greatly swollen and honeycombed by cystic spaces which were filled with a soft, gelatinous substance. Even in uninvolved areas, the cartilage seemed soft and degenerated; it had the appearance and texture of wet white blotting paper. Surfaces were irregular, and fibrous "adhesions" were in evidence. Zones of calcification were observed in several instances. In most of the cases there was

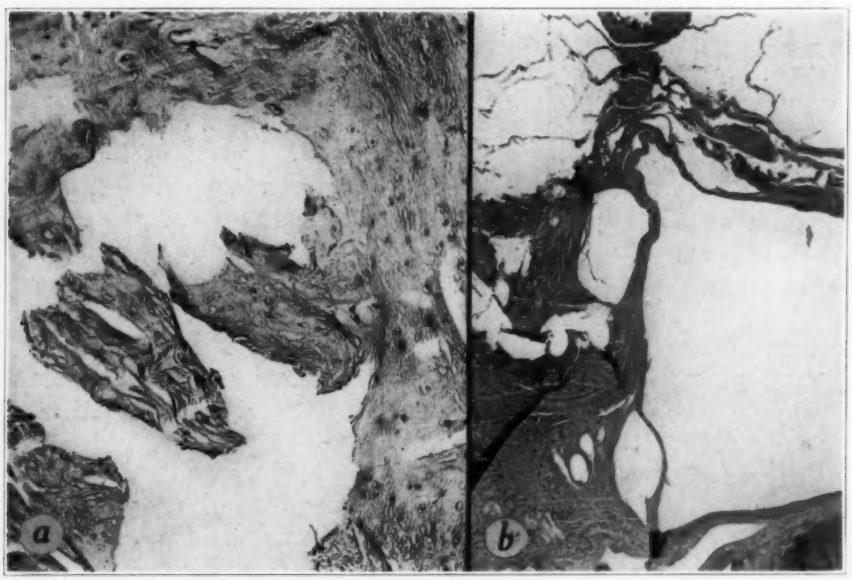

FIG. 5-A FIG. 5-B

Fig. 5-A: Photomicrograph (×80) of a cystic meniscus. Note the degeneration and rather extensive cyst formation. There is no endothelial lining. Hematoxylin and eosin stains were used.

Fig. 5-B: Photomicrograph (×25) of a cystic meniscus. Note the large cysts and also the replacement of cartilage by fibrous tissue. Hematoxylin and eosin stains were used.

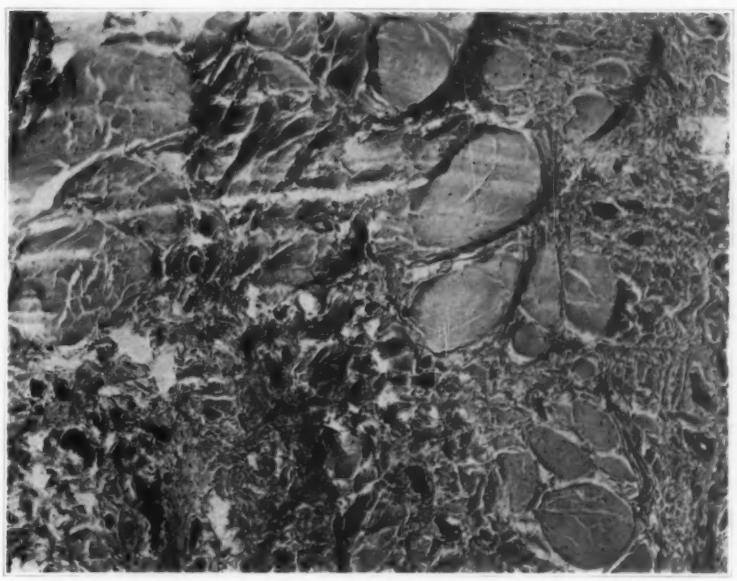

FIG. 6

Photomicrograph (×80) showing extensive fibrosis in a case of cystic disease of the meniscus. Hematoxylin and eosin stains were used.

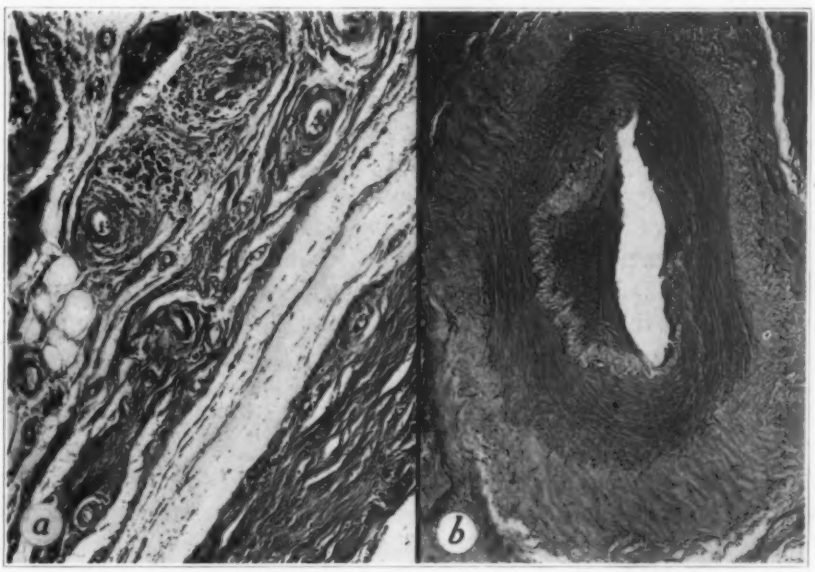

FIG. 7-A FIG. 7-B

Fig. 7-A: Photomicrograph (×80) of a cystic meniscus in an advanced stage. Note the fibrosis, vascularization, and chronic inflammatory changes. Hematoxylin and eosins stains were used.

Fig. 7-B: Photomicrograph (×80) showing sclerosis of vessels in a case of cystic meniscus. Hematoxylin and eosin stains were used.

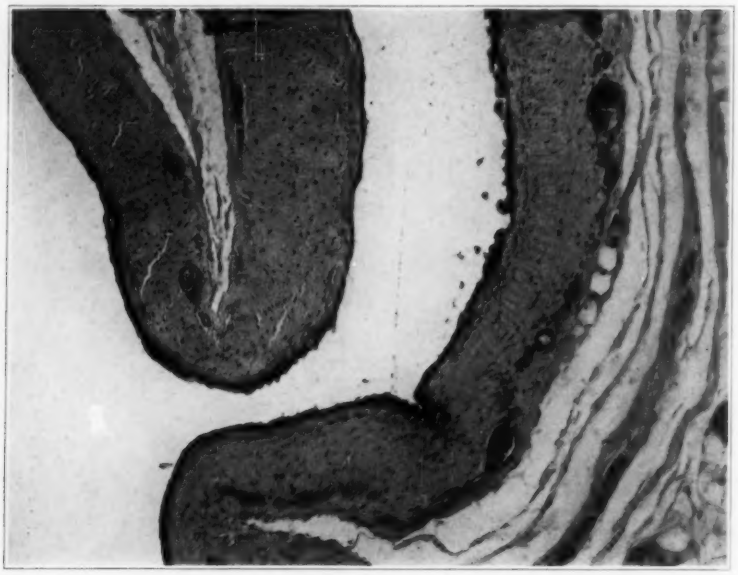

FIG. 8

Photomicrograph (×115) showing chronic infectious arthritis (villous synovitis). Contrast this picture with the degenerative lesions shown in Figs. 3, 4-A, 4-B, 5-A, 5-B, and 6. Hematoxylin and eosin stains were used.

associated with the diseased cartilage a variable amount of tissue which was soft and spongy in texture, like fibrous granulation tissue. In no instance, however, were there observed any extracartilaginous cysts such as were found in the cases in which tissue was not listed as "cystic semilunar cartilage".

In the heterogeneous group studied, there were a variety of conditions with a different gross picture in almost every case. In one, the appearance was that of hemorrhage into a bursal sac; in one, the appearance suggested inflammatory "villous" synovial membrane; in several, the material resembled myxomatous tissue; and in one, it resembled myxochondromatous tissue. In the remaining cases, the lesions were obviously smooth-walled cysts, usually ruptured, and usually containing mucoid material. The menisci seldom were present.

Microscopic Examination

Microscopically, the normal meniscus was seen to consist of rather acellular fibrocartilaginous tissue, which stained uniformly pink with hematoxylin and eosin (Fig. 3). Blood vessels were very scanty and thin-walled; lymphatic vessels and nerves were not observed. There was no evidence of degeneration, formation of cysts, or replacement of normal tissue by fibrous tissue. Calcification was occasionally noted.

In the group of cysts of the meniscus, changes were observed in varying grades of severity. The earliest of these changes appeared to

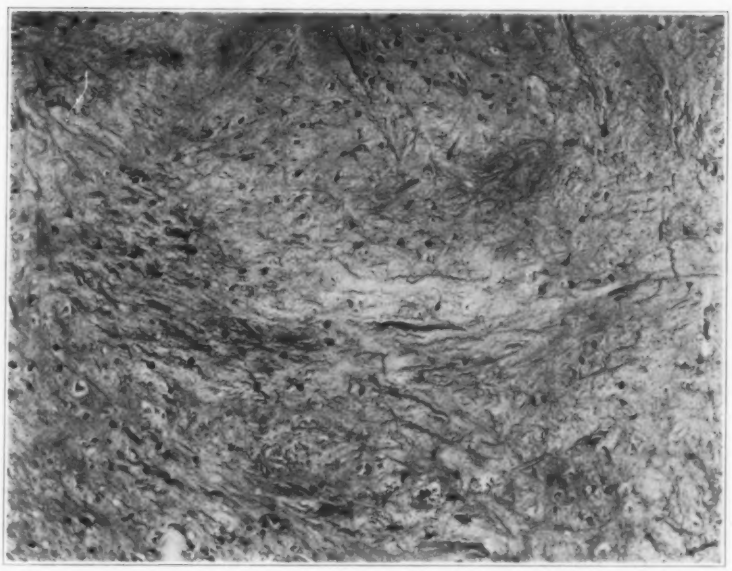

FIG. 9

Photomicrograph (×80) showing true myxochondroma of a meniscus. Hematoxylin and eosin stains were used.

be degeneration of the cartilage, which stained irregularly and contained areas of myxomatous softening. In a more advanced stage, clefts appeared in the degenerated portions (which frequently seemed necrotic), and enlargement of these clefts seemed to represent the cysts observed on gross inspection (Figs. 4-A and 4-B). In some the cysts were unilocular, in others they were multilocular, but in both varieties the lining was similar—degenerated fibrocartilage *without* endothelium (Figs. 5-A and 5-B). A second important change noted was replacement of the degenerated cartilage by vascular connective tissue. Arising probably from the points of cartilaginous attachment, this fibrous tissue could be seen creeping along the clefts, so to speak, and invading the cystic spaces mentioned previously (Fig. 5-B). In advanced instances, fibrosis was so extensive that only isolated islands of cartilage could be identified (Fig. 6). In some instances, the fibrous tissue was loose and myxomatous in texture, and highly vascular (Fig. 7-A). In others hyalinization was a prominent feature in a tissue that revealed marked thickening of the blood vessels, occasionally to the point of occlusion (Fig. 7-B). Old hemorrhages and chronic inflammatory changes were superimposed features in cases in which the condition had been longstanding. In these circumstances it became difficult to say with certainty that the process had its inception in cystic degeneration of the meniscus.

In the cases in the remaining group, some points of interest were demonstrated. In one case the picture was that of chronic infectious arthritis (villous synovitis) with proliferative overgrowth of the synovial

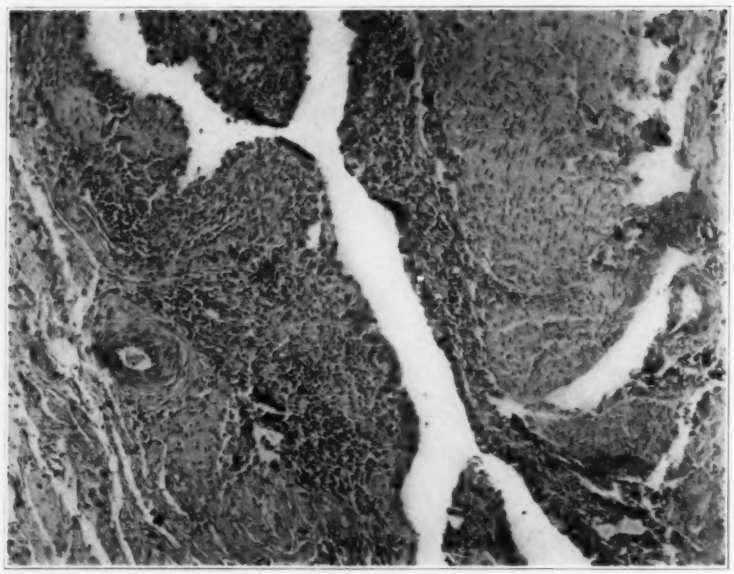

FIG. 10

Photomicrograph (×80) of a Baker's cyst. Note the lining of plump endothelial cells and hyaline fibrous-tissue wall. Hematoxylin and eosin stains were used.

membrane as a result of chronic inflammation (Fig. 8). In another, an old intracapsular hemorrhage of traumatic origin was characterized by a vascular wall of organized fibrin which surrounded masses of amorphous material probably representing old inspissated blood clot. In still another case, the microscopic picture was that of a cellular myxochondroma,—the only example in the series in which an actual tumor of the meniscus was present (Case 1, shown in Fig. 9). The rest of the material consisted of cystic tumors that did not obviously originate in the meniscus. Some of these were capsular, and others were extracapsular in origin; they were grossly classified as "ganglion cysts" or "Baker's cysts". However, it was found microscopically that all these cysts had one basic feature in common,—they were all lined by endothelium (Fig. 10). In some instances this endothelium was swollen,—the cells being filled with a substance that stained weakly positive for mucin. (In these cases a similar substance appeared inside the cysts and was regarded as being probably a secretion.) In others the lining endothelium was flattened—apparently under tension—with the stage of active secretion past. This endothelial lining was supported by a fibrous connective wall which varied considerably in thickness as well as in vascularity. Loose areolar tissue and bits of muscle also were found, especially in cases in which the cysts were extracapsular.

DISCUSSION OF CASES

In only one of the four cases reported herein in detail was there an

endothelial lining to the cystic tumor. In this case it was noted at the time of the operation that there was apparent involvement of the medial meniscus. Whether the condition in this case represented an extensive overgrowth of such a cyst it is difficult to say. This tumor was so large that any inclusion in its walls of part of the meniscus, except where it was attached, was out of the question. In pathological examination of Baker's cysts, an endothelial lining was noted, and it is possible that in this case the condition was similar in its origin to such cysts. It might be called a "parameniscal cyst", a term used by Bennett and Shaw in describing some unusual cysts of the menisci.

In Case 1, a true myxomatous tumor of the meniscus may have been present. Examination of the patient's knee two years after operation revealed no evidence of recurrence.

Case 3 is without doubt a case of cystic meniscus of unusual size. In Case 4 so much bone change and such extensive damage to the meniscus were present that identity of the true changes was lost, and the authors could find no tissue remaining which resembled the meniscus. At the time of this report, the patient in Case 4 was greatly relieved, and had no evidence of recurrence of the tumor.

REVIEW OF THE LITERATURE

Osseous changes in cystic menisci have been reported by Fairbank and Lloyd who observed such changes in two cases. In both cases there were multiple cysts, and in one the eroded portion of the tibia was one and one-quarter inches (3.1 centimeters) in length, and one inch (2.5 centimeters) in depth. Roentgenograms in both cases showed punched-out regions situated just at the border of the articular surface of the lateral tuberosity of the tibia. These cases would seem to be similar to the authors' Case 4.

Bennett reviewed theories concerning the causation of cysts of the meniscus, and among these theories were the following:

1. Trauma is followed by hemorrhage into the injured region, mucoid degeneration of the hematoma occurs, and the fabrication of a mesothelial cyst wall is brought about by compression of the surrounding fibrocartilage;

2. Obliterative changes in the arterioles of the parameniscal tissue are responsible (Ledderhose);

3. The condition is congenital in origin (Ollerenshaw);

4. Trauma plus congenital anomaly is the etiological background (Majer);

5. The condition is the result of the activity of cells secreting gelatinous fluid (King);

6. Synovial inclusions, akin to cysts that arise in synovial membrane and to ganglia which develop in the tendon sheaths, cause the condition (Geschickter and Lewis);

7. Synovial implants into cartilage at the time of trauma are responsible (Zadek and Jaffe).

Bennett and Shaw stated that in the differential diagnosis of cysts of the meniscus, a bursa arising from beneath the medial and lateral ligaments, and true synovial outpouchings from the joint constitute the most common problem. They further stated that the distinction between parameniscal cysts and true cysts may be difficult, because primary cysts arise from the lateral edge of the cartilage and immediately dissect outward through the capsule, thus being parameniscal in most of their growth. These authors further wrote that the lining of these cysts varies from a thin mesothelial-like wall to a rather thick wall, seemingly composed of compressed fibrous-tissue cells. In view of this, the lesion in the authors' Case 2 may represent a parameniscal cyst which invaded this capsular tissue, and became surrounded by a thin endothelial wall.

A review of various articles in the literature on cysts of the meniscus reveals that some confusion exists as to causation of the condition. Most authors accepted the views expressed by Ebner, who in 1904 first described the condition as a "ganglion of the cartilage of the knee joint". One author, King, who studied these cysts with special stains to demonstrate the Golgi apparatus, recently stated, "From the point of view of the Golgi apparatus therefore there is no evidence of 'degeneration' in the areas of mucoid accumulation until a very late stage", and concludes, "The tissue cells of ganglia and cysts of the menisci contain droplets of mucinoid material, etc., which resemble the results of cellular activity more closely than those of protoplasmic disintegration . . . Ganglia and cysts of the menisci therefore may be regarded as abnormal new 'joint spaces' and not fundamentally 'degenerative'."

This seems to be worthy of serious consideration. Although the controversy concerning the causation of ganglia and cystic tumors filled with mucinous material cannot be settled herein, it is the authors' feeling that to say that they all represent a degenerative change may be a statement without sufficient foundation in fact. One of the authors (R. K. G.) subscribed to this view in another discussion of the causation of bursae and ganglia elsewhere, but he has always felt that in some cases a true secretory function of the lining cells when present in such cysts would more truly describe the physiological picture. Thus, in Case 2, something more than simple degeneration must have taken place to have produced a tumor of such size. Moreover, although the lining wall of this cyst did have an apparent endothelial membrane, active secretion could not be demonstrated. The work of Vaubel in demonstrating active mucinous secretion by synovial cells in tissue cultures has always seemed to the authors to be significant in this respect. Thus, the condition in this case may have represented parameniscal cyst with an actively secreting lining membrane.

Burman and Sutro, in their review of cystic changes in menisci, reported on two tumors or "pseudotumors" of the menisci. These were fibrous tumors not clearly classified. Whether or not the lesion in the

authors' Case 1 can be a true tumor of the meniscus may be open to doubt. Results of pathological study would lead to the belief that it is.

COMMENT

In the light of the present studies, cystic changes of the menisci must be looked upon as examples of degeneration rather than as examples of true neoplasia. It is doubtful whether even the term "hypertrophy" can be used in this connection. The basis for such changes appears to be cystic degeneration which is followed by extensive repair through fibrosis. This is not difficult to understand, when it is considered that repair of specialized tissues, such as cartilage, frequently is effected by tissues of a lower order. The part (if any) played by damage to nutrient blood vessels is a matter of speculation. The hyaline and occlusive changes observed may or may not be of importance, and whether or not the changes are of the nature of small infarctions cannot easily be decided.

In addition to cysts of the meniscus, the authors have even more frequently found Baker's cysts or popliteal cysts, which may at times be filled with myxomatous or gelatinous tissue. Such should be classified as endothelial cysts. More extensive tumors, three of which may represent more advanced stages of these conditions have also been reported.

A single case of true myxoma has been included in the group. The purpose in presenting this case is to emphasize the fact that such tumors may exist, and that, although in some cases they may represent extension of popliteal cysts or cysts of the meniscus, they may at times become so large and damage adjacent structures so severely, that by losing their identity through such growth, they cannot be definitely classified in either of these groups.

CONCLUSIONS

From a discussion of four cases of unusual mucinous tumors of the knee joint, including two which are probably cysts of the meniscus (one with an unusual amount of bone change), one which is probably an unusually extensive development of a parameniscal cyst, and one which is a true myxomatous tumor of the meniscus, it appears that cysts of the menisci apparently are not true neoplasms, but represent the end results of degeneration.

Such cysts may sometimes be distinguished from other cysts in the region of the knee joint by the absence of endothelial lining.

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BLADE-PLATE INTERNAL FIXATION FOR HIGH FEMORAL OSTEOTOMIES *

BY W. P. BLOUNT, M.D., MILWAUKEE, WISCONSIN

Osteotomy of the femur just above or below the lesser trochanter has been accepted and variously modified for the correction of a number of abnormal conditions about the hip. The importance of this procedure has been increased by its use in the treatment of ununited fractures and (occasionally) recent [2, 3] fractures of the neck of the femur. The difficulty of maintaining the desired position has been emphasized by Brackett, and Unger and Waring. A plaster spica may hold the fragments in some cases, but good position cannot be regularly assured without some additional fixation device. Schanz [12] advocated the use of crossed screws held in position by wire. Riedel simplified and improved this technique by adding a plate across the ends of the screws. Plaster fixation for a period of about eight weeks was still necessary. In young individuals this was of little consequence. In old patients, particularly those with stiffness of the knees from previous cast fixation, it was a great disadvantage.

For several years, the writer has tried various methods of eliminating the cast. It was accomplished by multiple pin fixation, but with a considerable hazard introduced by the protruding pins. In addition, the pin

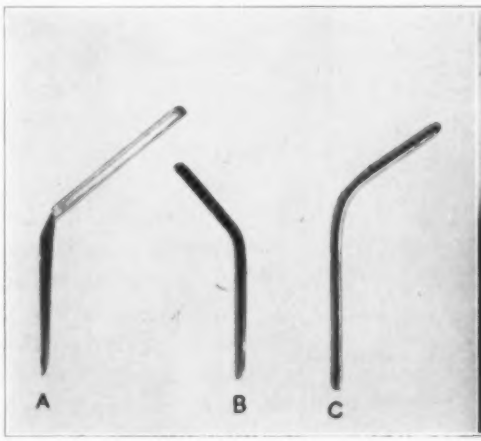

FIG. 1-A

A. Neufeld nail for fixation of trochanteric fracture.
B. Neufeld nail for fixation of trochanteric osteotomy.
C. Moore nail for fixation of trochanteric fracture.

FIG. 1-B

Neufeld nail (*B*) in position, fixating a high femoral osteotomy of the McMurray-Putti type.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 20, 1943.

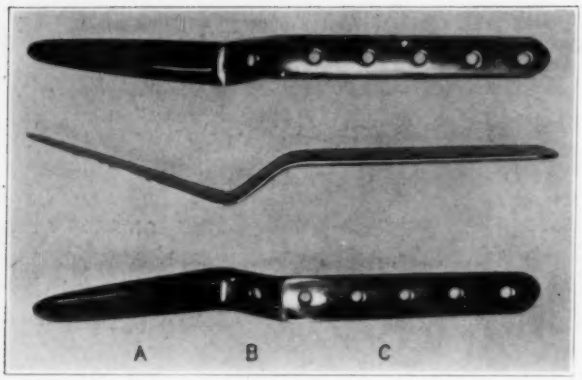

FIG. 2

Standard double-angle blade-plate for internal fixation of high femoral osteotomies. The angles and even the shape may be modified to suit the individual case. *A:* blade, *B:* gooseneck, and *C:* plate.

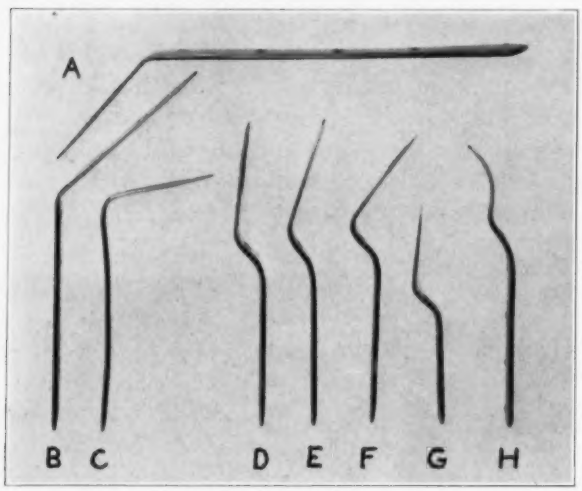

FIG. 3

Various types of blade-plates.

A: Single-angle blade-plate, with a blade two and one-half inches long and a plate six or seven inches long, for subtrochanteric fractures;

B: Single-angle blade-plate, with a blade three to four inches long, for trochanteric fractures;

C: Single-angle blade-plate, bent abruptly, for use in high osteotomy for rotation or femur shortening;

D: Double-angle blade-plate for low osteotomies;

E: Standard double-angle blade-plate;

F: Double-angle blade-plate for high osteotomies;

G: Small double-angle blade-plate for use in a child;

H: Double-angle blade-plate with a curved blade, for use with atrophic trochanters where there is no femoral neck.

fixation was insecure. Various types of internal fixation were tried, but none was entirely satisfactory.

In 1937 Thornton published the description of an ingenious modification of Smith-Petersen's nail for the internal fixation of trochanteric fractures. Neufeld simplified this technique and has recently also developed a modification for the internal fixation of an osteotomy of the upper end of the femur (Figs. 1-A and 1-B). In November 1941, Moore demonstrated a similar but simpler device for the internal splinting of trochanteric fractures, which the author recognized as the long sought principle of fixating osteotomies. Because of the abrupt variations in the structure of the bone at this level, it was necessary to use a device which combined a blade above with a plate below the site of osteotomy. By inserting a second angle, three-quarters of an inch below the first (Fig 2), a double-angle blade-plate was evolved, which securely held an angulated high femoral osteotomy. Any degree of angulation or rotation was accurately maintained. Undesirable angulation or rotation was prevented.

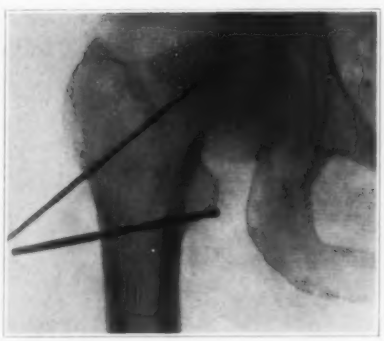

FIG. 4-A

FIG. 4-B

After insertion of a guide pin for the blade and a drill to locate the site of the osteotomy, anteroposterior and lateral roentgenograms are taken on the operating table.

The blade-plate has since been simplified and adapted for a variety of purposes (Fig. 3).

OPERATIVE TECHNIQUE

With the patient on an ordinary operating table, and a long x-ray tunnel under the hips, the patient is surgically prepared and draped so as to expose the hip and leave the entire affected extremity free. The skin and subcutaneous fat are incised longitudinally just posterior to the trochanter, from the level of its tip for eight or nine inches distally. In fat individuals it is helpful to add a short anterior curve at the distal end. The fascia lata is divided directly over the femur. The fibers of the vastus lateralis are split longitudinally down to bone from their origin distally for four inches. The periosteum is elevated to either side. An anvil-retractor is inserted subperiosteally in front to retract the entire soft-tissue mass including the tensor fasciae femoris. A blade retractor is inserted posteriorly. The vastus lateralis is freed from the base of the trochanter by sharp dissection. About one-half inch below the upper reflection of this muscle, a guide pin is inserted at the proposed location of the blade. The shape, size, and location of the blade will vary considerably with the individual indications. The site of the osteotomy is selected three-quarters of an inch below the guide pin, and a drill is inserted as a marker. Anteroposterior and lateral roentgenograms are then taken (Figs. 4-A and 4-B). The femur is internally rotated for the anteroposterior view, and is flexed to a right angle, abducted, and rotated slightly internally for the lateral view.

While the roentgenograms are being developed, the drill is withdrawn and the shaft of the femur is exposed for four inches below it. Bleeders are tied. Because the blade-plate will soon cover up the site of the osteotomy, it is necessary to complete the lateral third of the osteotomy (Fig. 5) before the blade is driven. In performing the high osteotomy, it is well to remove a narrow wedge with the base laterally to

FIG. 5

The lateral third of the osteotomy is completed before the blade is driven.

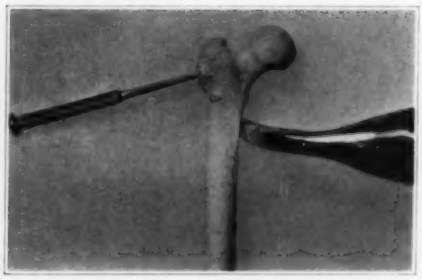

FIG. 6

With an osteotome, a hole is cut in the cortex as a start for the blade.

FIG. 7

In driving the average blade, the blow may be struck with a hammer on the end of the plate.

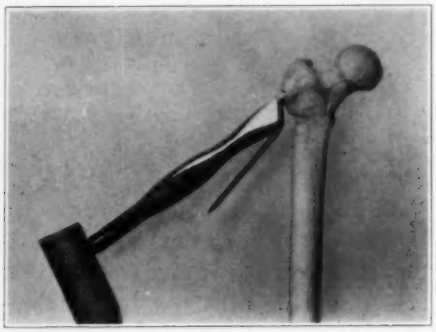

FIG. 8

In driving a single-angle, or a double-angle blade-plate with an acute proximal angle, a driver is necessary.

FIG. 9

The angle between the plate and the long axis of the femur is measured by a special protractor. This angle is obviously the ultimate angle of the osteotomy.

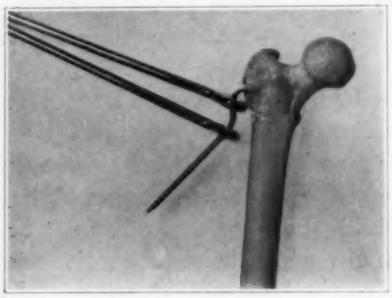

FIG. 10

The angle between the plate and the long axis of the femur may be changed with bending irons.

facilitate angulation. In the lower osteotomy, this is not necessary. With a small osteotome, a start is made for the blade (Fig. 6). It is well to round off the distal margin of a thick cortex so that the gooseneck will come to lie close against the femur. The direction of the guide pin is

Models illustrating the high and the low Schanz osteotomies, using a blade-plate.

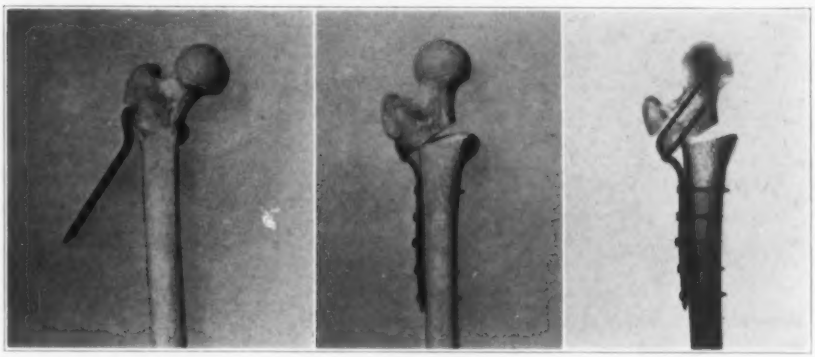

FIG. 11-A_1 FIG. 11-A_2 FIG. 11-A_3

Fig. 11-A_1: High osteotomy has been started and the blade driven.
Fig. 11-A_2: High osteotomy has been completed and fixated.
Fig. 11-A_3: Roentgenogram showing the completed high osteotomy.

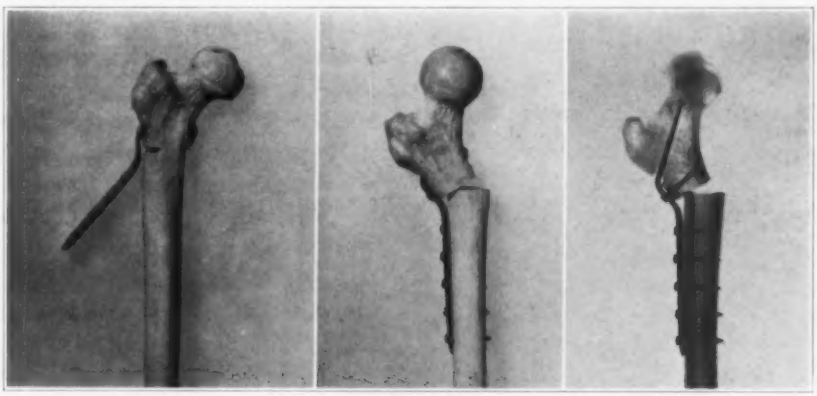

FIG. 11-B_1 FIG. 11-B_2 FIG. 11-B_3

Fig. 11-B_1: Low osteotomy has been started and the blade driven.
Fig. 11-B_2: Low osteotomy has been completed and fixated.
Fig. 11-B_3: Roentgenogram showing the completed low osteotomy.

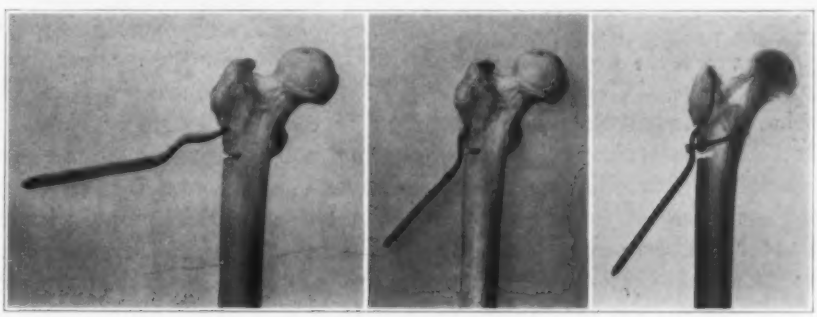

FIG. 11-C_1 FIG. 11-C_2 FIG. 11-C_3

Fig. 11-C_1: Low osteotomy has been started with a curved blade.
Fig. 11-C_2: The curved blade has been driven into the trochanter so that penetration of the neck was not necessary.
Fig. 11-C_3: Roentgenogram showing the curved blade within the trochanter, and a screw in the upper fragment for added security.

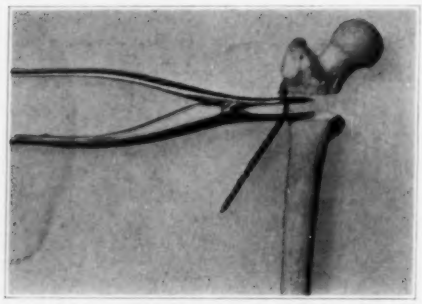

FIG. 12

The bone ends are completely separated by a spreader.

FIG. 13

The pusher is offset to displace the distal fragment of bone medially in spite of the interposed plate.

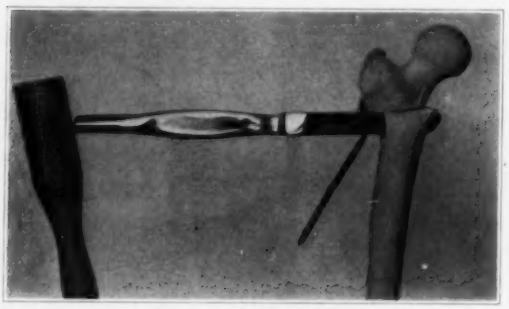

FIG. 14

The distal fragment is displaced medially with the pusher, while the extremity is abducted.

estimated, or measured with the protractor, and necessary changes of location and direction are made as the blade is driven. If it is desired to have the apex of the angle of the osteotomy anterior, as well as medial, the blade should be driven so that the plate will protrude somewhat posterior to the femur.

Often the blow may be struck on the end of the plate (Fig. 7). In high osteotomies which require a more acute angle between the blade and the gooseneck, a driver will be necessary to transmit the force in the long axis of the blade (Fig. 8). This instrument will be equally useful in driving the single-angle blade-plate.

Before the blade is driven completely home, the angle between the plate and the shaft of the femur is measured (Fig. 9). It should correspond to the (previously selected) angle of osteotomy. The distal angle of the blade-plate may be changed with small bending irons if it is not correct (Fig. 10). The driver is then used to seat the gooseneck snugly against the bone. A long screw is inserted through the hole in the gooseneck and into the trochanter, usually engaging the opposite cortex (Fig. 11). Now the osteotomy is completed. It is a distinct advantage not to have the bone cut before the blade has been driven home and the exact angle of the plate has been obtained. The osteotomy should be carefully completed with drill and thin osteotome, unless the surgeon prefers a motorized or Gigli saw. Care should be taken to avoid splintering the bone with the formation of undesirable spicules. The bone ends should be completely separated to assure mobility at the site of the osteotomy (Fig. 12).

In the high osteotomy, the distal fragment should be displaced medially. At times there is considerable difficulty in obtaining this displacement. A special pushing iron will be found convenient for this

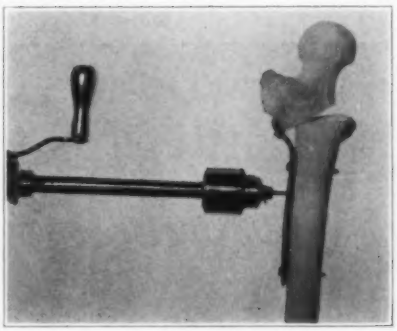

FIG. 15

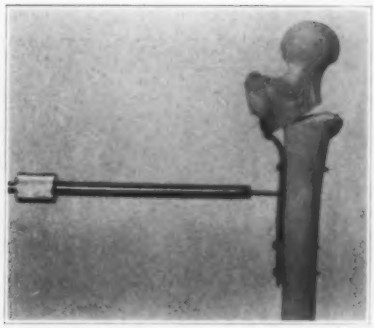

FIG. 16

Fig. 15: The plate is clamped to the femur and holes of exactly the proper size are drilled. For the standard Sherman-type screws, the diameter should be seven sixty-fourths of an inch for soft bone, and eight sixty-fourths for hard. A motor saves time and energy.

Fig. 16: Screws must be of the proper length to extend through both cortices.

purpose (Fig. 13). It is an adaptation of the one originally used by Schanz, with an offset to allow a direct push in spite of the interposed plate. While the femur is being abducted, a few sharp blows on the proximal end of the distal fragment will displace it medially (Fig. 14). The plate is clamped to the shaft of the femur while screws of the proper length are inserted (Figs. 15 and 16). A check-up roentgenogram is taken before the wound is closed. No external fixation is necessary.

FIG. 17

A model to illustrate the appearance of the osteotomy six months after operation. The model has been reconstructed from roentgenograms and from the appearance of the bone when observed after the removal of the blade-plate.

DISCUSSION

The blade-plates and screws are now made of S. M. O. stainless steel. When they have been removed after six months or more, almost no reaction has been found. There is no need to take out the blade-plates in older individuals. In children and young adults, it is probably a good plan to remove the metal after six months. The second operation will require almost the same incision as the first. Considerable bleeding will be encountered.

The double-angle blade-plate should be available in three standard sizes, a small one with a two-inch blade for small femora, a medium one with a blade of two and one-half inches for average femora, and the large size with a three-inch blade. The last is intended for the occasional case of ununited fracture of the femoral neck in which the surgeon wishes to impale the head on the end of the blade. This procedure is not recommended unless there is a viable head, without degenerative change and in good position. Not infrequently there is cephalad or posterior displacement of the distal fragment, which adjusts itself better if the head is not

FIG. 18-B

FIG. 18-A

Case 1. F. H., male, aged forty-seven. Anteroposterior and lateral views of the right hip taken on December 13, 1941, show an ununited fracture of the femoral neck of one year's duration. The Trendelenburg sign was positive on the right and negative on the left.

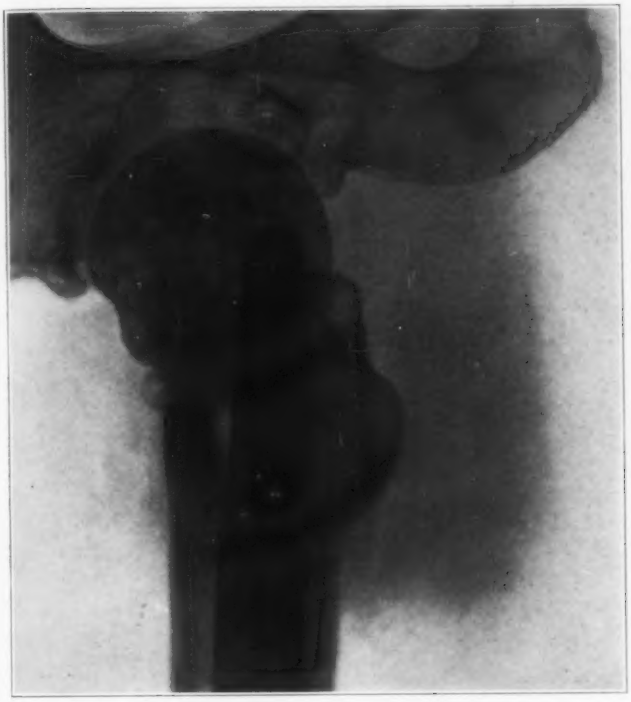

FIG. 18-D

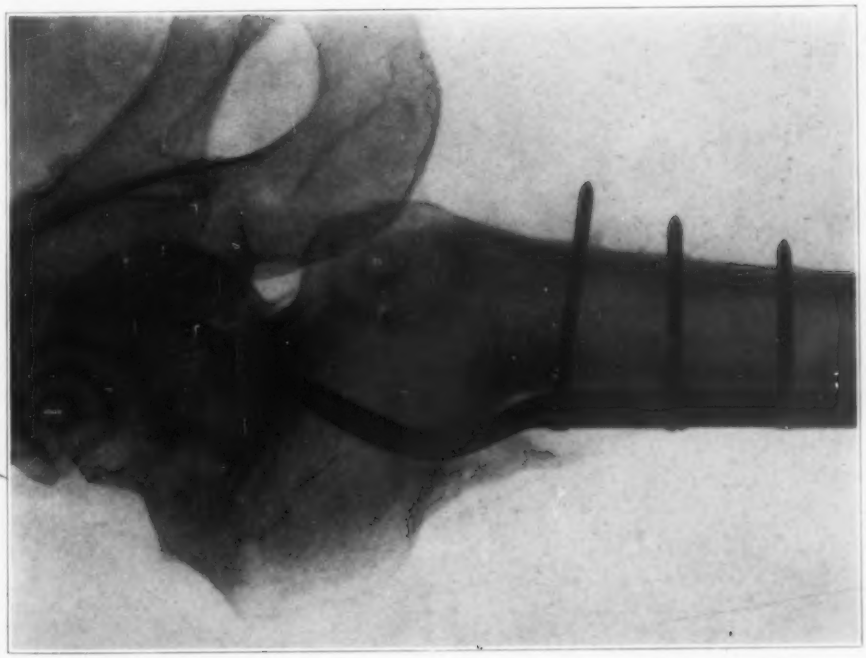

FIG. 18-C

Case 1. Anteroposterior and lateral views of the right hip dated November 28, 1942, one year after osteotomy with blade-plate fixation. (In recent cases an additional screw has been used in the proximal fragment.) He began walking with crutches eight days after the operation, and left the Hospital on the twelfth day. Full weight-bearing was possible in eight weeks. He returned to farm work in fourteen weeks. The Trendelenburg sign was negative.

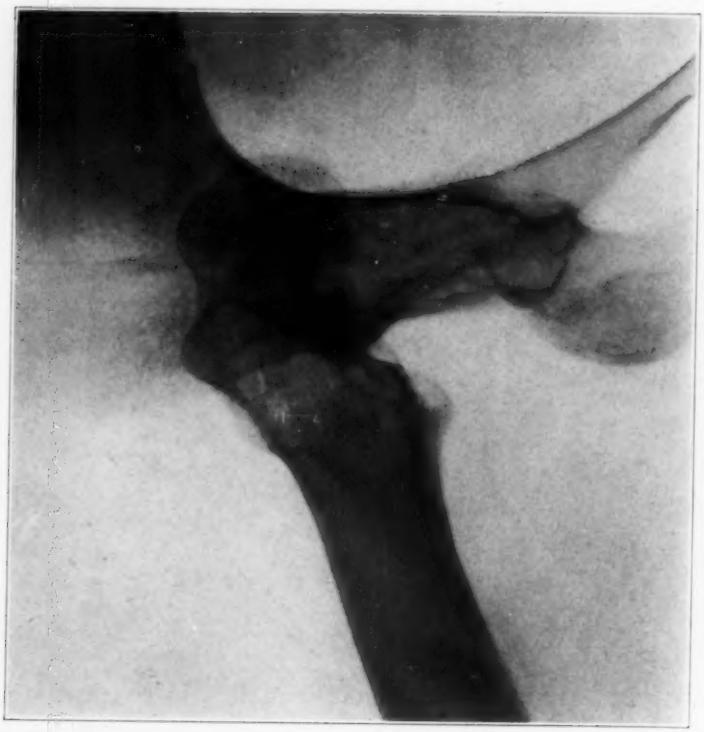

FIG. 19-B

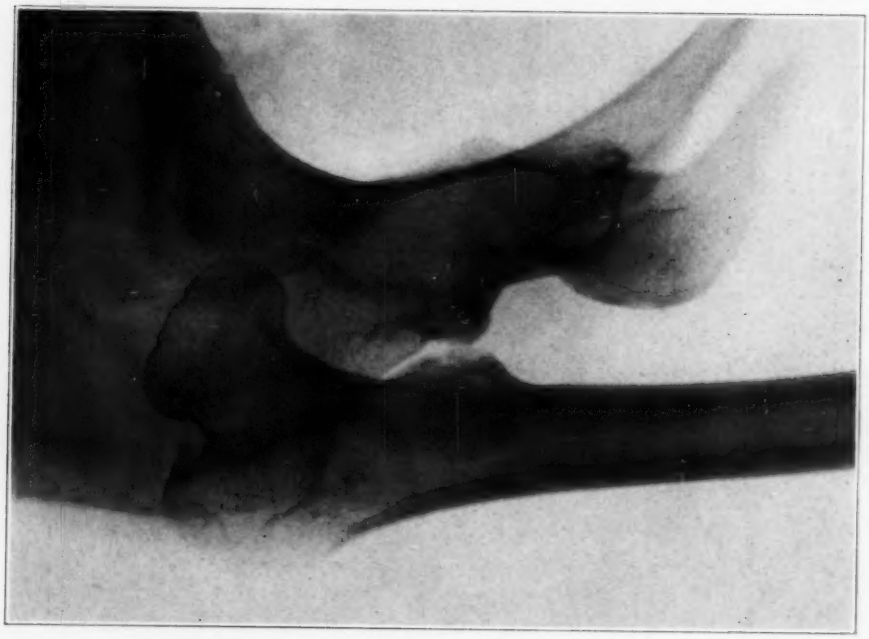

FIG. 19-A

Case 2. R. J., female, aged thirty. Anteroposterior and lateral views dated August 29, 1942, show congenital dislocation of the right hip which had been untreated. The patient had a marked sway-back and a positive Trendelenburg sign. Pain in the right hip and backache had developed recently.

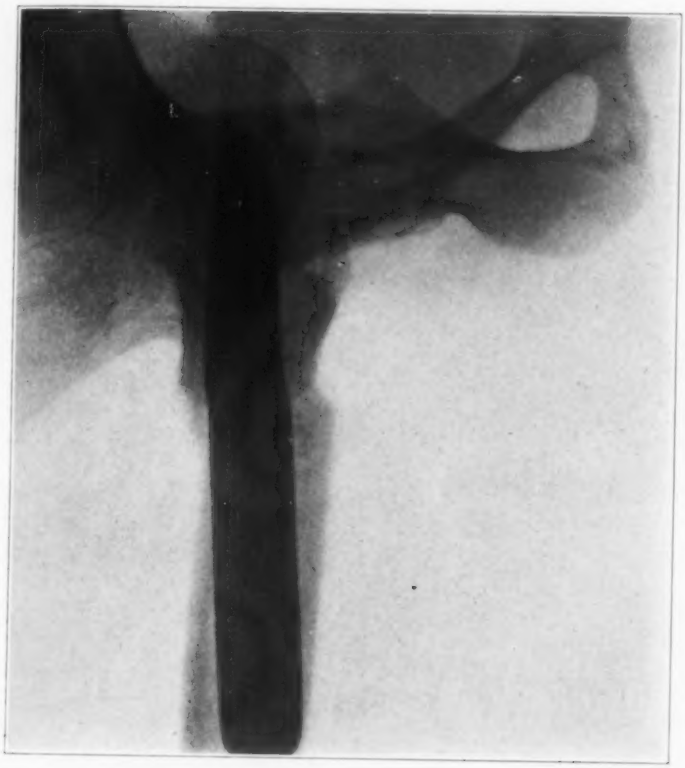

FIG. 19-D

Case 2. Anteroposterior and lateral views dated December 14, 1942, three months following a low osteotomy on the right side. She sat on the edge of the bed in one week, and walked on crutches in two weeks. In one month she walked down four flights of stairs to a taxi. The Trendelenburg sign was negative on the right, and symptoms had disappeared.

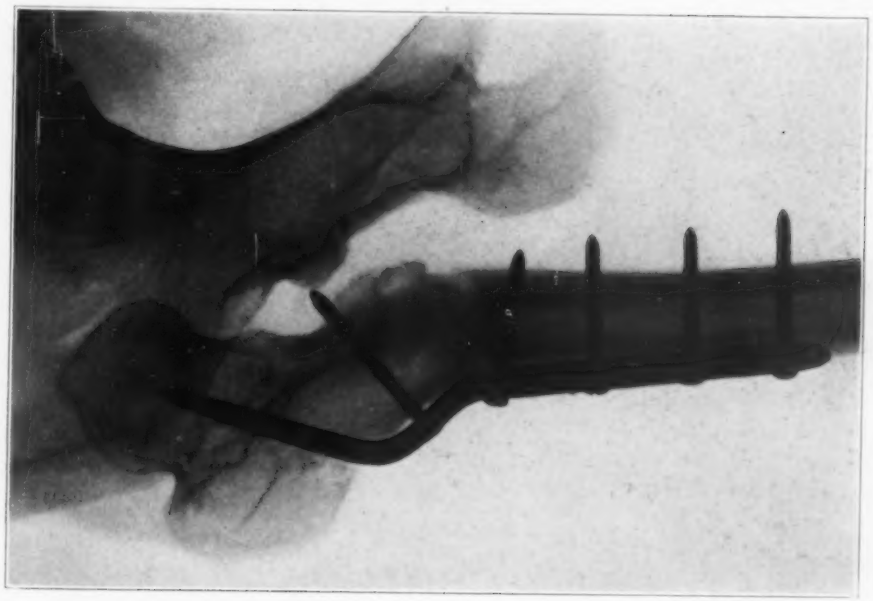

FIG. 19-C

FIG. 20-B

Case 3. A. S., male, aged thirteen, had had excessive weight for four years, and a limp on the left for one year. This had become worse with a lunge just prior to examination. The Trendelenburg sign was negative on the right and positive on the left. The patient had a typical Fröhlich habitus. Antero-posterior and lateral views of the left hip, taken October 17, 1942, show a typical adolescent coxa vara with considerable, but not complete, displacement of the femoral epiphysis.

FIG. 20-A

FIG. 20-A

of the femoral epiphysis.

FIG. 20-C

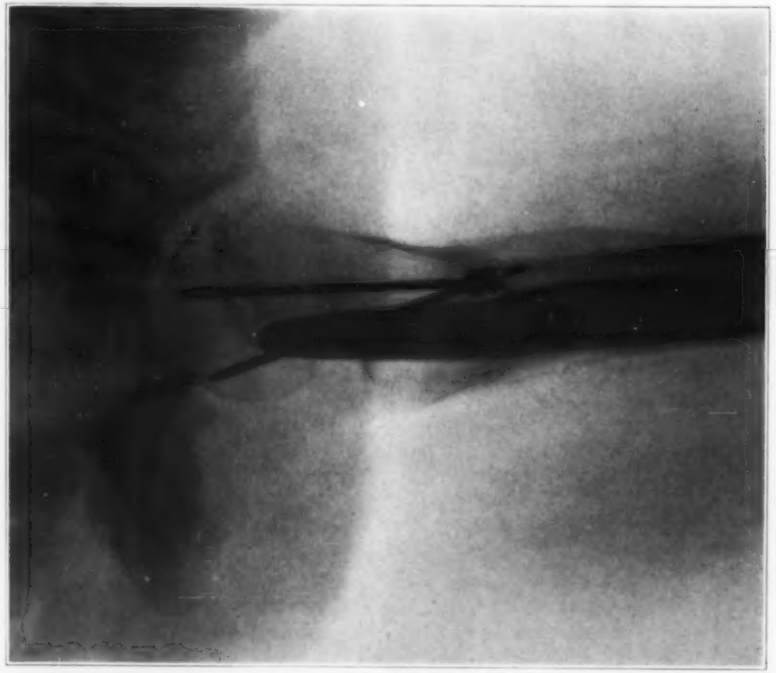

FIG. 20-D

Case 3. Anteroposterior and lateral views of the left hip dated December 12, 1942, following drilling and pinning of the femoral head and neck, combined with subtrochanteric osteotomy for correction of coxa vara and rotation deformity, on October 22, 1942. Internal fixation was accomplished with a blade-plate. The patient was discharged from the Hospital walking with crutches on November 7, 1942. All hardware was removed on February 12, 1943.

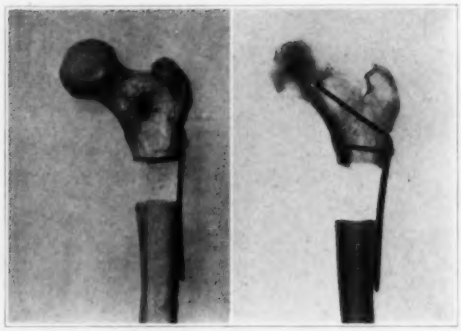

FIG. 21-A_1 FIG. 21-A_2

Femur shortening with the use of single-angle blade-plate fixation.

Fig. 21-A_1: The blade has been driven and a screw inserted through the proximal hole. A segment of bone has been removed just distal to the lesser trochanter.

Fig. 21-A_2: Roentgenogram of the bone in Fig. 21-A_1.

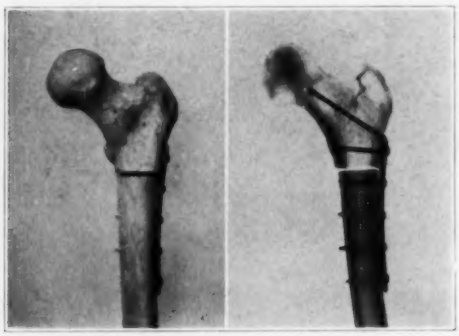

FIG. 21-B_1 FIG. 21-B_2

Fig. 21-B_1: The bone ends are held securely in place by screwing the plate to the distal fragment.

Fig. 21-B_2: Roentgenogram of the bone in Fig. 21-B_1.

impaled. If the fracture is fresh enough to reduce, it is well to fixate the head with removable wires or nails before the insertion of the blade. The use of too long a blade has resulted in its gradual protrusion through the head into the acetabulum.

When the neck is markedly absorbed with a wide zone of fibrous tissue, it is better to use a short blade. After operation, the fragments will adjust themselves to a stable position. Occasionally the neck will be entirely absorbed, and the trochanter will be so thin that even a two-inch blade will be too long. In such a case, it is advisable to use a short blade which is curved on the flat (Fig. 3*H*). It is introduced at the same point, but follows the course of an arc within the trochanter as in Figure 11-C. The usual screw is inserted through the gooseneck into the proximal fragment. A powerful hold may thus be obtained on an atrophic trochanter from which the blade might otherwise pull out.

In performing an angulation osteotomy, it is well to make a tracing of the roentgenogram and to cut out the pattern prior to the operation. A line is drawn on it in the long axis of the femur. The actual operation is then carried out on the pattern. Angulation of the femur can be accurately measured with a protractor. The position of the pattern may then be secured with a paper clip or glue, and the pattern placed against the roentgenogram of the pelvis in confirmation of the proposed angulation. Forty degrees is the average angle in cases of ununited fracture.

In congenital dislocation of the hip, the angle should be 5 or 10 degrees less. Excessive angulation of a low osteotomy will require a supracondylar osteotomy to correct the knock-knee. Osteotomies to

correct deformities such as coxa vara and coxa plana may require only slight angulation, but considerable rotation.

The blade-plate should be laid on the angulated pattern in exactly the position it is to occupy. Slight changes in its angles will usually be necessary. For the high osteotomy, the angle between the gooseneck and the blade will be about 100 degrees, with the blade inserted higher up (Fig. 11-A). In a very low osteotomy, the angle between the gooseneck and the blade should be more obtuse than the standard. In this case, the blade is inserted lower down and angled upward (Fig. 11-B).

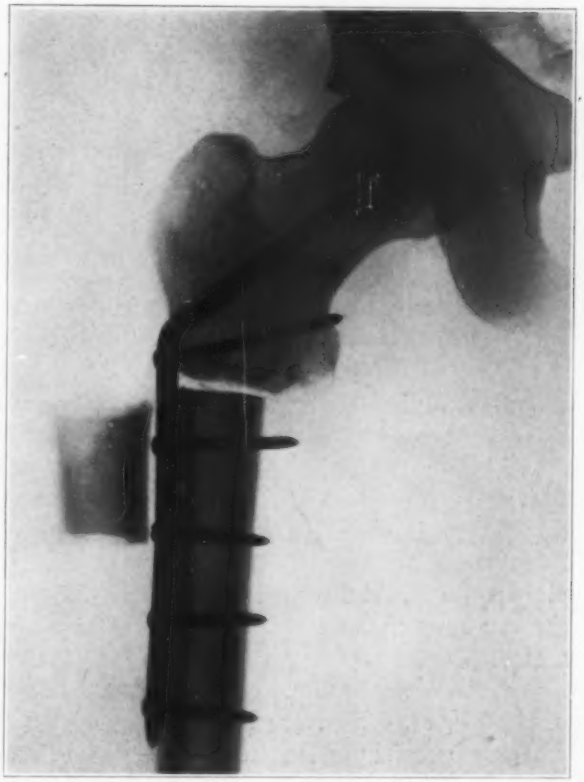

FIG. 22

Case 4. R. W., male, aged sixteen. Anteroposterior roentgenogram following femur shortening with single-angle blade-plate fixation. The excised piece of bone was laid on the cassette.

There are situations in which the standard sizes and shapes will not fill the bill. Modification of them may be made quickly with a vise, a cold chisel, and a grindstone. The author has used a miniature blade-plate (Fig. 3*G*) in a child for the sake of accurate fixation. The second operation for removal of the metal is preferable to the insecurity of Schanz screws in an active child.

The principles of femoral osteotomy were beautifully stated by Schanz in 1925 and thoroughly reviewed in his book. They were studied exhaustively by Pauwels, and were expressed mathematically in his monograph in 1935. These principles were recently well reviewed by Schumm. They have stood the test of time, and brook no radical change if the optimum result is to be obtained. In his original work, Schanz advocated a high osteotomy for most ununited fractures of the femoral neck. In this article, he discussed the criteria by which the level may be determined, and emphasized the necessary lower level if the head is degenerated.

Perhaps we should more often combine a low osteotomy with excision of the head as he suggested. Gaenslen mentioned seven drawbacks to the Schanz osteotomy as used in congenital dislocation of the hip. Three of these were untoward angulation, stiffness of the knee from the cast, and non-union from insecure fixation. All three are eliminated by the use of a blade-plate.

As late as 1941, Speed and Smith enumerated the virtues of an osteotomy, but still preferred the bone-grafting operation where it could be performed. But their illustrations show a case in which the end result of an osteotomy was as good as that which could have been obtained by any bone-grafting operation. The author can show similar cases. With the increased popularity and improved technique of osteotomy, which should logically follow the use of internal fixation, a preference for the more formidable bone-grafting operation may decline.

Speed and Smith, and many others prefer the McMurray or Putti type of osteotomy. The greatest advantage of the Schanz operation over this type is in the angulation of the proximal fragment which re-establishes the function of the abductor muscles. By the use of the blade-plate in the McMurray operation, some angulation may be obtained, and the displacement of the fragments may be accurately controlled without a cast.

Perhaps the best end result is obtained by an osteotomy at the level of the lesser trochanter, with both angulation of the proximal fragment and some medial displacement of the distal fragment. With this type of operation, the stiffness, the positive Trendelenburg sign, and the fatigue limp of the McMurray operation are eliminated. In the very high osteotomy, the knock-knee is not troublesome.

In the past year the author has used blade-plate internal fixation of high osteotomies for the following conditions: ununited fracture of the neck of the femur (Figs. 18-A, 18-B, 18-C, and 18-D), neglected congenital dislocation of the hip (Figs. 19-A, 19-B, 19-C, and 19-D), coxa vara (Figs. 20-A, 20-B, 20-C and 20-D), coxa plana, femur shortening (Fig. 22), and recently in combination with a second osteotomy for vicious ankylosis in lieu of arthroplasty (Figs. 23-A and 23-B). Additional cases have been supplied by friends who have tried the method. On the whole the results have been reported as very satisfactory. The chief complication has been marked bone atrophy of the trochanter with insecurity or pulling out of the blade. For this type of bone, the curved-on-the-flat blade (Fig. 11-C) may be the best solution. The use of a screw in the proximal fragment should not be omitted.

A single-angle blade-plate has been modified for use in trochanteric (Figs. 24-A, 24-B, 24-C, and 24-D) and subtrochanteric fractures, and in rotation and femur-shortening * osteotomies (Fig. 22). The tapering blade easily "finds" and remains within the neck of the femur. The an-

* This use was suggested by Captain Hugh Smith at the 1943 Meeting of The American Academy of Orthopaedic Surgeons.

FIG. 23-A

FIG. 23-B

Fig. 23-A: Case 5. B. S., male, aged twenty. Anteroposterior view of the right hip shows atrophic arthritis. This involved the hips and knees which had been ankylosed and painless for one year. The left lower extremity was in good position, the right in external rotation of 80 degrees.

Fig. 23-B: Anteroposterior view of the right hip two months following a double osteotomy on October 1, 1942. A non-union was created, and the rotation was corrected by resection of the neck of the femur with the removal of a wedge, based anteriorly. At the same time a subtrochanteric osteotomy was performed and fixated with a blade-plate. Angulation with the apex medially was combined with further correction of rotation deformity. Range of motion has been steadily increasing for four months following the operation.

FIG. 24-A

FIG. 24-B

CASE 6. R. P., female, aged sixty-nine. Anteroposterior and lateral views taken on December 18, 1942, show the right hip immediately following a trochanteric fracture.

FIG. 24-D

Case 6. Anteroposterior and lateral views of the right hip on January 2, 1943, following fixation with a single-angle blade-plate and the addition of a Moore nail to anchor a loose fragment of the trochanter. No external fixation was necessary. Discomfort lasted only a few days.

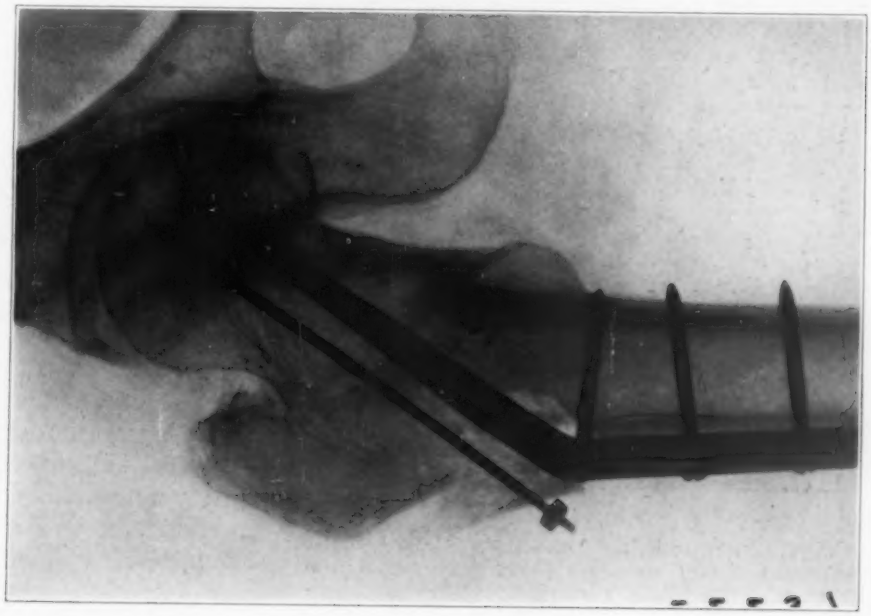

FIG. 24-C

gle and the contour of the plate may be changed readily prior to or during the operation with small bending irons. While objections have been offered to the blade-plate on theoretical grounds, it is ideally simple, and has worked out practically.

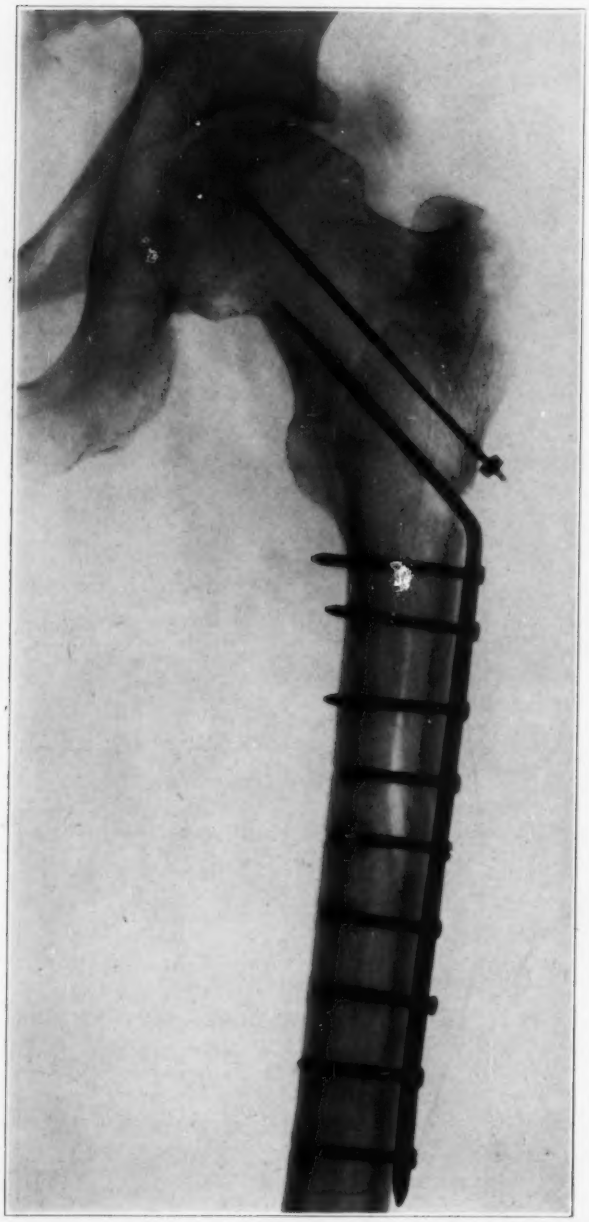

FIG. 25

Case 7. F. S., male, aged fifty-nine. Anteroposterior roentgenogram of a combined trochanteric and subtrochanteric fracture with fixation with a single-angle blade-plate. Additional security was obtained with one Moore nail. The patient walked with crutches after ten days

In subtrochanteric non-union, a single-angle blade-plate with a seven-inch plate has been used for fixation of the fragments in connection with a massive bone graft. No external fixation was used, and the patient was ambulatory with crutches in three weeks. It was most advantageous to mobilize the knee.

The fixation secured by a blade-plate is effective in securing rapid bony union, and most patients may walk without crutches before eight weeks. Although early weight-bearing is contra-indicated in a fresh fracture of the femoral neck, it is desirable in most lesions for which a high osteotomy is performed. The method is particularly applicable in adults where a cast would be a hardship. It would also appear to have some place in postwar surgery.

SUMMARY

1. A blade-plate is used for the internal fixation of high femoral osteotomies as well as fractures.

2. The cast is eliminated.

3. The patient may walk with crutches in less than two weeks.

4. Internal fixation with this device permits accurate maintenance of any desired angulation.

5. Untoward angulation is prevented.

6. Rotation is accurately controlled.

7. Blade-plate fixation has been used successfully in trochanteric and subtrochanteric fractures, and in osteotomy for ununited fracture of the femoral neck, congenital dislocation of the hip, shortening of the femur, coxa vara, coxa plana, and (combined with a second osteotomy) for correction of vicious ankylosis.

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THE BRIDGING OF THE VERTEBRAL BODIES IN TUBERCULOSIS OF THE SPINE

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The findings in the active stage of tuberculosis of the spine,—namely, bone destruction, osteoporosis, and abscess formation, are well known. Healing takes place by fibrosis, organization of the abscesses, resorption of sequestra, osteogenesis, and at times bony fusion between the involved vertebrae.[7] This healing is seen in the roentgenogram as sclerosis of bone, sharper delineation of the bones, and decrease in the size of the abscesses. The phenomenon of bridging of the vertebral bodies at the site of the tuberculous bone involvement is not widely known. Willis stated, "little has been added to Pott's description of the gross pathology of this disease, in fact many of his observations have been forgotten, and must need be periodically recalled to mind to maintain a complete description of the lesion". Willis attributes this oversight to the fact that certain pathological findings described by Pott were not in accord with so-called typical roentgen-ray findings, and, therefore, the tubercle bacillus was ruled out as a factor in their production. He further stated, "though Pott described calcification of intervertebral ligaments and production of new bone in his autopsy findings, many roentgenologists mistakenly insist that these changes are contradiagnostic of tuberculous lesions". The bridging of the vertebral bodies in tuberculous spondylitis has been described by Cofield, Schipporeit, Steindler, and Milgram. The bridging of the vertebral bodies in tuberculous spondylitis may be overlooked, and has come to be associated rather with pyogenic infection of the vertebra. For this reason, the following cases of bridging of the vertebral bodies in proved cases of tuberculosis of the spine are being presented.

CASE REPORTS

CASE 1. E. H., a white male, thirty-two years old, was admitted to Holmes Hospital, Cincinnati, on May 6, 1940. On September 17, 1939, the patient had been stooping over at work, when he had been struck in the lower back by a heavy piece of lumber. He had had severe pain, but had continued to work for six weeks, although movement aggravated the pain. After November 1939, he had been confined to bed because of the pain. He had lost forty-four pounds, and weighed 103 pounds. After March 1940, he had had fever and increasing weakness. On examination, he presented a sallow complexion and emaciation, and complained of much pain. The lumbar spine showed a moderate kyphosis. There was severe pain on deep pressure laterally over the transverse processes in the region of the second and third lumbar vertebrae. The extremities revealed evidence of loss of weight and weakness. The patient's temperature ranged be-

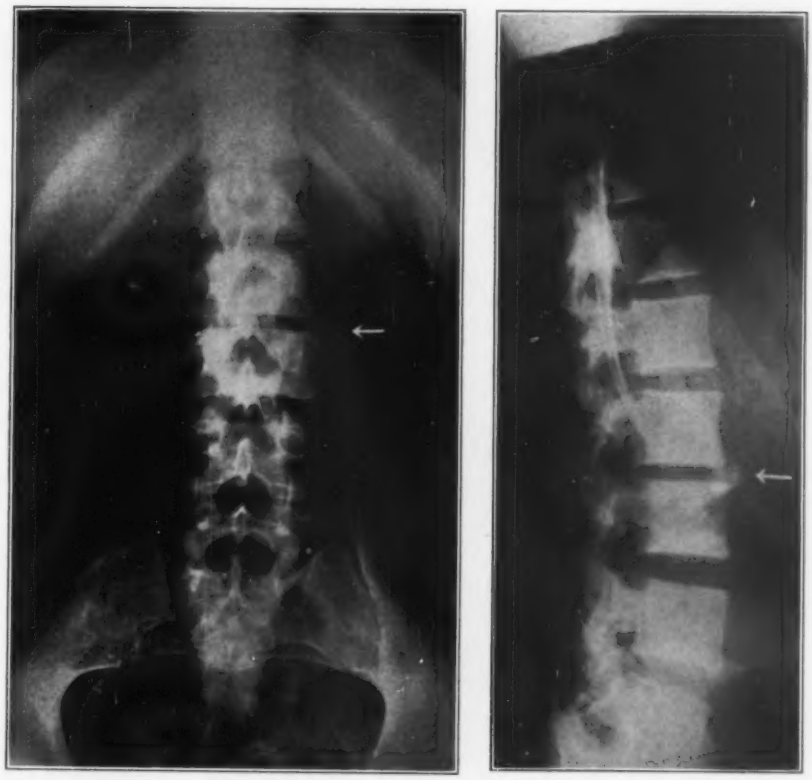

FIG. 1-A FIG. 1-B

Fig. 1-A: Case 1. E. H. May 21, 1940. Roentgenogram shows bridging between the second and third lumbar vertebrae on the left side by an amorphous calcium deposit.

Fig. 1-B: May 27, 1940. Roentgenogram shows narrowing of the intervertebral disc between the second and third lumbar vertebrae. There is an amorphous calcified mass anterior to the interspace between the second and third lumbar vertebrae.

tween 97.6 degrees and 102.4 degrees Fahrenheit during the greater part of his stay in the Hospital. He had a moderate anaemia and slight leukocytosis. The tuberculin test was strongly positive. On May 31, 1940, an operation was performed under local anaesthesia. Through a left lumbar paravertebral incision, the transverse processes of the second and third lumbar vertebrae were exposed. A thin, watery, purulent exudate was encountered. Culture of this pus revealed no growth. A biopsy specimen from the soft tissues in the region where the pus was encountered revealed tuberculous granulation tissue. The wound drained persistently. A tuberculous abscess subsequently developed, which pointed in the region of the left sternoclavicular joint, but did not have to be aspirated and did not drain. In October 1940, an abscess developed in Petit's triangle on the right side. This was aspirated on several occasions, but finally drained spontaneously. The patient continued on a downhill course. Signs of involvement of the central nervous system developed, followed by convulsions, disorientation, and death on December 12, 1940.

Roentgenograms of the lumbar spine were taken on May 21, 1940, in the anteroposterior view (Fig. 1-A), and on May 27, 1940, in the lateral view (Fig. 1-B). Roentgenograms of two different dates are used in order to portray the changes from the

roentgenographic viewpoint. Narrowing of the intervertebral disc between the second and third lumbar vertebrae is revealed. There is mottling of the body of the third lumbar vertebra. The sclerosis is most marked in the inferior portion of the body of the third lumbar vertebra. The height of the body of the third lumbar vertebra does not appear to be diminished. Extending downward along the left side of the body of the second lumbar vertebra, the second lumbar interspace, the third lumbar vertebral body, and part of the third lumbar interspace is seen a fairly dense calcified deposit. This calcified deposit bridges the second lumbar interspace. Such a deposit is seen to the right of the inferior portion of the body of the third lumbar vertebra. The outline of both psoas shadows is seen to be increased in size, especially on the left side. Lying anterior to the second lumbar interspace is a calcified deposit. Subsequent roentgenograms taken at intervals revealed further narrowing of the second lumbar interspace, further decrease in the density of the anterior portion of the third lumbar vertebral body, and an increase in the thickness of the bridge extending across the third and second lumbar interspaces, and, also, part of the first lumbar interspace.

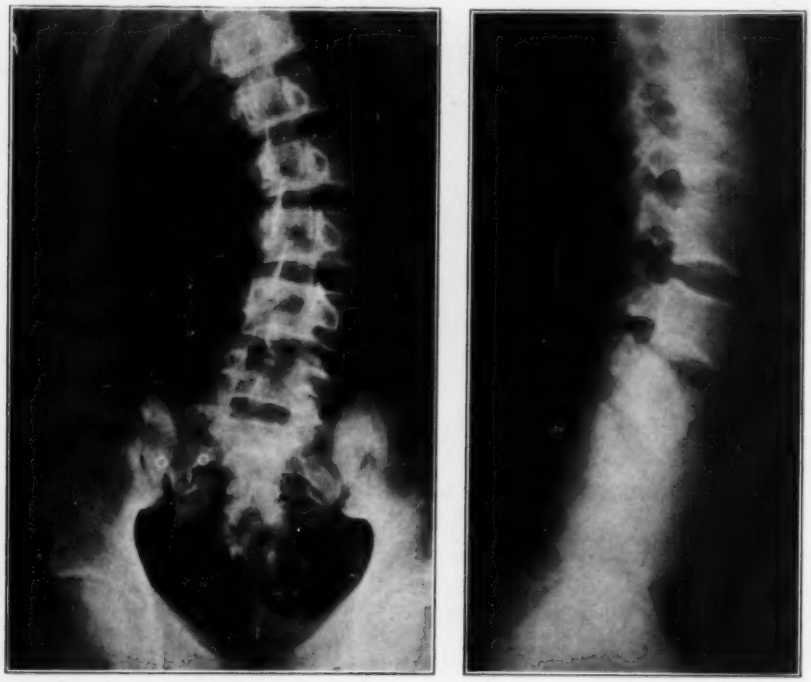

FIG. 2-A FIG. 2-B

Case 2. J. J. July 27, 1937. There is no evidence of bridging of the vertebrae at this time.

In view of the history of trauma, persistent pain in the back, loss of weight, septic type of temperature, leukocytosis, and the bridging as seen in the roentgenograms, the process was considered to be due to osteomyelitis of the lumbar vertebrae. Tuberculosis and malignancy were considered. The finding of tuberculous granulation tissue, in the absence of open sinuses, and the absence of other organisms in culture and smear, proved the case to be one of tuberculosis of the spine.

This case demonstrates the great need for differentiation between

FIG. 2-C

FIG. 2-D

Case 2. J. J. April 15, 1941. There is bony bridging between the bodies of the third and fourth lumbar vertebrae. The interspace between these vertebrae is narrowed.

pyogenic and tuberculous infections. The sclerosis of the body of the second lumbar vertebra and the bridging of the bodies of the second and third lumbar vertebrae are findings which have been described as characteristically occurring in pyogenic spondylitis.[9] This lesion must be differentiated from pyogenic infection of the vertebral bodies and discs, from degenerated disc lesions with vertebral bridging, and from osteoarthritis of the spine.

CASE 2. J. J., a colored male, eighteen years old, was admitted to the Hamilton County Tuberculosis Hospital on April 9, 1937. His illness dated back to February 1937, when he had had a left pleural effusion. During the early part of his stay at this institution, a right pleural effusion, pericardial effusion, and peritoneal effusion developed. Cultures and guinea-pig inoculation of the fluid from the pleural and pericardial cavities did not yield any evidence of tuberculous infection. Roentgenograms of the chest revealed no evidence of a parenchymal lesion. In July 1937, nodules developed over the trunk and extremities. Guinea-pig inoculation of the fluid obtained from these skin lesions yielded evidence of a tuberculous infection. The patient had a slight gibbus at the apex of a scoliotic curve in the lumbar region. This area was tender, and there was tenderness, spasticity, and fullness to the left of the gibbus. There was a palpable psoas abscess on the left side of the abdomen. In October 1938, clinical and roentgenographic evidence suggested that a tuberculous dactylitis of the right index finger had developed. In December 1938, the psoas abscess ruptured spontaneously in the left groin. The resultant sinus tract closed in February 1940. The patient was allowed to walk in

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 3. R. L. T., Jr. July 15, 1941. Roentgenogram shows destructive changes in the fourth and fifth lumbar vertebral bodies and bony spurs arising from the lateral margins of the fourth lumbar vertebra.

Fig. 3-B: July 15, 1941. Roentgenogram shows destructive changes involving the bodies of the fourth and fifth lumbar vertebrae and bony bridging between the third and fourth lumbar vertebrae.

April 1940, and was discharged in June 1940. He has been followed in the Orthopaedic Clinic of the Cincinnati General Hospital, and has continued to do well.

Roentgenograms of the lumbar spine taken on July 27, 1937, in the anteroposterior and the lateral views (Figs. 2-A and 2-B) reveal a scoliosis of the lumbar spine with convexity to the left. There is a slight narrowing in the height of the disc between the fourth and fifth lumbar vertebrae, evidence of destruction of the superior portion of the body of the fifth lumbar vertebra, two calcified shadows lying anterior to the fourth lumbar interspace, and a destructive lesion involving the left sacro-iliac joint. There appears to be some increase in the size of the outline of the left psoas shadow. Subsequent roentgenograms, taken prior to spontaneous rupture of the left psoas abscess in December 1938, revealed dense bony bridging between the fourth and fifth lumbar vertebrae. This dense bony bridging is best depicted, in so far as the clarity of the roentgenograms is concerned, in anteroposterior and lateral views of the lumbar vertebrae taken on April 15, 1941 (Figs. 2-C and 2-D). Here the new-bone formation is dense and extends upward as a spur to the third lumbar interspace. The lesions of the fourth and fifth lumbar vertebrae, bordering on the fourth lumbar interspace, appear sclerotic and sharply delineated, as does the lesion in the left sacro-iliac joint, suggesting a healed lesion.

CASE 3. R. L. T., Jr., a colored male, thirty-two years old, was admitted to the Hamilton County Tuberculosis Hospital on August 8, 1937. He was discharged on February 13, 1938, with a diagnosis of far-advanced, chronic fibroid pulmonary tuberculosis. On April 17, 1939, he was readmitted to the Hospital because of a reactivation of his pul-

monary lesion. Tubercle bacilli were found in his sputum. On July 30, 1939, he began to complain of pain in the lumbosacral region, which lasted a short time. On April 6, 1940, pain again developed in the lumbosacral region and radiated into the left hip. He had a gibbus at the fourth and fifth lumbar vertebrae, and there was spasm of the lumbar portion of the sacrospinalis. He had been confined to bed since his readmission. A palpable fullness was present in the right iliac fossa, and on November 5, 1941, a thick greenish pus was aspirated from this fossa. The smear of the pus showed degenerating pus cells and no organisms. The culture was negative. Guinea-pig inoculation with the pus yielded evidence of tuberculous infection.

Roentgenograms of the lumbar spine taken on July 15, 1941, in the anteroposterior and lateral views (Figs. 3-A and 3-B) reveal extensive destructive changes involving the bodies of the fourth and fifth lumbar vertebrae and the disc between them. The height of these two vertebrae is considerably decreased. The superior portion of the body of the fourth lumbar vertebra is very dense and appears to be sequestrated. There is dense bridging between the anterior portions of the bodies of the third and fourth lumbar vertebrae. Both the right and left psoas shadows in their lower portions are increased in size, and there appears to be a dense prevertebral swelling extending distally from the second lumbar vertebra. There are several dense calcified shadows anterior and to the left of the body of the third lumbar vertebra and the third lumbar interspace, probably representing calcified lymph nodes.

Case 4. D. C., a white male, twenty-five years old, was admitted to the Jewish Hospital of Cincinnati on January 9, 1941. The patient's illness dated back to the early

Fig. 4-A

Fig. 4-B

Fig. 4-A: Case. 4. D. C. January 10, 1941. Roentgenogram shows destructive changes involving the first and second lumbar vertebrae and a unilateral psoas abscess on the left side.

Fig. 4-B: January 10, 1941. Roentgenogram shows bony bridging between the bodies of the first and second lumbar vertebrae.

part of 1938. He had complained of pain in the muscles of the lower part of the back, and subsequently had had pain in both hips, but continued to perform heavy work. He also complained of weakness. In the spring of 1940, soreness had developed in the left groin, and he had begun to limp and had noted a lump in the left groin. In June 1940, a swelling had developed in the left lumbar region. The weakness persisted. The mass in the left groin became larger, and he lost weight. On examination there was a palpable psoas abscess and a small fluctuant mass in Petit's triangle on the left side. There was slight gibbus at the first lumbar vertebra, but no restriction of motion in the hips. On January 10, 1941, the psoas abscess was aspirated, and 1120 cubic centimeters of thin green pus was obtained. Guinea-pig inoculation with this pus yielded evidence of tuberculous infection. The abscess was aspirated on several occasions, and it then stopped filling. About July 1941, the abscess in Petit's triangle started to drain spontaneously while the patient was at home. This sinus tract was closed by the time he returned to the Hospital in December 1941. At this time it was noted that the patient had a destructive lesion in the left hip. He is still recumbent in a hip spica cast.

Roentgenograms of the lumbar spine made in the anteroposterior and lateral views (Figs. 4-A and 4-B) on January 10, 1941, revealed marked sclerosis of the bodies of the first and second lumbar vertebrae, destructive changes in the adjacent portions of the bodies of the first and second lumbar vertebrae, and spurring and bridging between the bodies of the first and second lumbar vertebrae. The outline of the psoas shadow on the left side was markedly enlarged, but no enlargement was noted on the right side. The prevertebral shadow opposite the bodies of the twelfth thoracic and lumbar vertebrae was enlarged, and there was a radiopaque shadow in the eleventh intercostal space on the left side, probably representing a calcified lymph node.

Case 5. K. C., a white male, thirty-nine years old, was admitted to the Cincinnati General Hospital on July 14, 1939. He complained of pain and disability of the left hip and the back. His present illness had begun abruptly on June 6, 1939, with aching in the region of the left hip. He recalled episodes of low-back pain dating back nine years. This pain was associated with pain radiating to both buttocks. With the onset of his recent back pain he had noted some tender glands in the left inguinal region. On examination he appeared to be a well-developed and well-nourished white male. The left hip was flexed 35 degrees, and there was some muscle spasm about the left hip. Attempts to move this joint produced pain, but with care the hip could be flexed to a right angle, while other motions were restricted. There were several firm tender lymph nodes in the left inguinal region, and tenderness over the lateral aspect of the left thigh just anterior to the greater trochanter. There was marked spasm of the lumbar musculature, and motions of the lumbar spine were markedly restricted. On July 13, 1939, aspiration of the left psoas abscess yielded 125 cubic centimeters of thick yellow pus. Culture of the pus was negative, but a direct smear of the pus revealed acid-fast bacilli. Roentgenograms taken on May 22, 1940, revealed destructive changes in the left hip. These became progressively worse, and on November 30, 1940, an arthrodesing operation was performed. On April 30, 1941, the left hip was noted to be fused on clinical and roentgenographic examination. The patient was up walking without any complaints referable to the back or hip, although no surgery had been done on the back.

Roentgenograms of the lumbar spine taken on September 10, 1941, in the anteroposterior and lateral views (Figs. 5-A and 5-B) revealed considerable atrophy of the bones, and a lesion between the second and third lumbar vertebrae. Here the intervertebral disc had almost completely disappeared. There was bridging of the second lumbar interspace anteriorly and on the left side, and evidence of bridging between the fourth and fifth lumbar vertebrae, with narrowing of this interspace, and what appeared to be old destructive changes in the adjacent portions of the bodies of the fourth and fifth lumbar vertebrae. Bridging was also present between the third and fourth lumbar vertebrae anteriorly and on the right side. The outlines of the psoas shadows were increased. Several radiopaque shadows opposite the lower thoracic vertebrae probably represented calcified lymph nodes.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 5. K. C. September 10, 1941. Roentgenogram shows destructive changes between the bodies of the second and third lumbar vertebrae and the fourth and fifth lumbar vertebrae. Bony bridging is seen.

Fig. 5-B: September 10, 1941. The intervertebral disc between the second and third lumbar vertebrae shows considerable loss of substance, and bony bridging is evident between the bodies of the second, third, fourth, and fifth lumbar vertebrae.

The lesions noted in the foregoing cases occurred in adults ranging in age from eighteen to thirty-nine years. Three of the five patients were white males and two were colored males. The lesions were found only in the lumbar region of the spine. Was it possible that the grinding action of the respiratory excursions[8] and the greater tendency of the vertebral bodies to collapse prevented the formation of similar bony bridges in the thoracic area of the spine? Three cases were not included in this paper. These showed bony bridging associated with destructive lesions of the vertebrae and tuberculous lesions elsewhere, but since the tubercle bacillus was not isolated or its manifestations proved they were not included. Four of the cases presented were proved to be tuberculous, by obtaining the acid-fast organism on direct smear in one (K. C.); by guinea-pig inoculation in two (R. L. T. and D. C.); and by histopathological evidence in one (E. H.). The proof in these cases was obtained from the pus or granulation tissue in the region of the osseous tuberculous process. In the fifth case (J. J.), the skin lesions proved to be tuberculous after inoculating guinea pigs with pus from these lesions. All of these cases

showed either a unilateral or bilateral psoas abscess. In none of the cases in this series were pyogenic organisms isolated on culture or smear of the pus.

In observing the roentgenograms of Case 5 (K. C.), consideration of the thought that primary invasion of the intervertebral disc may occur cannot be excluded. Compere and Garrison stated that, in tuberculosis of the spine, primary invasion of the disc does not occur because the adult disc has no blood supply. They stated that the disc is resistant to invasion by tuberculous infection. This phenomenon was similar to that described by Phemister on the action of tuberculous infection on articular cartilage. But Compere and Garrison state that the disc can be destroyed by tuberculous pus secondarily. Yet Badgley and Doub state that in tuberculous spondylitis the primary site of involvement might be central, anterior, or intervertebral. The intervertebral type of involvement was predicated on the work of Smith who stated, "Nutritive channels were observed in sections from young healthy discs". Smith concluded, "The mode of nutrition of the discs is by blood-channels which pierce the cartilaginous plates from the marrow of the vertebral bodies". Böhmig, quoted by Beadle, also showed that in youth the cartilage plate has a blood supply. Thus in youth, when the largest percentage of cases of tuberculous spondylitis occurs, the tubercle bacillus could be carried to the intervertebral discs by blood channels. Could the adult type of involvement of the intervertebral disc be explained by a reactivation of a previously implanted dormant focus? Or could the adult type be explained on the basis of infection carried to a granuloma in the disc? In the healing process, in a prolapse of the disc into the spongiosa of the vertebrae, blood vessels may grow in and form a granuloma.[2] Under the circumstances, Beadle stated, where "a free communication exists between spongiosa and disc tissue", extension of infection to the disc itself can occur. However, he also states that this vascular scar tissue "would . . . be a fairly resistant barrier to infection". The question still remains as to whether the disc can be involved primarily by tuberculous infection, dependent upon the presence or absence of circulation in the disc.

Cofield reported this lesion as occurring in 10 per cent. of a series of 100 cases of tuberculosis of the spine. Two of his cases were proved; five showed evidence of pulmonary tuberculosis; and six showed evidence of a psoas abscess. In five of these, roentgenographic evidence of bony bridging was present before the possibility of secondary infection could be cited as cause for the new-bone formation.

Willis stated, "calcification of soft tissues and decalcification of bone are matters of local biochemical conditions, the former associated with anemia and ischemia, the latter with active hyperemia. These two factors, in turn, are dependent upon the reaction of the affected tissue to the local irritant. This distention of intervertebral ligaments and joints by tuberculous pus or granulation tissue may result in decrease of circulation, edema and calcification of the intervertebral ligaments. In this way

affected vertebrae may be bridged and ankylosed by new formed bone, though the vertebrae previously showed bone absorption and destruction". Cofield expressed the opinion that the location of the lesion in a superficial position in the vertebra may be a factor in the periosteal production of new bone, and that mechanical irritation in a movable portion of the spine might be another factor in the production of this new bone, which is considered an attempt at repair. Cleveland believes that this bridging is due to elevation of the anterior longitudinal ligament, or its lateral expansion, and irritation and activity of the osteogenetic layer of the ligament. The bridging apparently does not represent a healing process, but rather is a reaction to mechancial irritation, caused by elevation of the anterior longitudinal ligament. Does this bone production present evidence of reaction to secondary infection? The foregoing would refute this, as would also the absence of secondary invaders in culture and smear.

Is the bony bridging adequate for immobilization of the involved vertebra or is spinal fusion necessary? Cofield's autopsy specimen revealed the second and third lumbar vertebrae to be the site of extensive carious degeneration, yet the bridging extended from the twelfth thoracic to the fourth lumbar vertebrae. In four of the authors' cases, roentgenographic examination revealed apparent true osseous fusion between adjacent vertebral bodies. In one of the cases (E. H.), the bridging from a roentgenographic point of view was inadequate, and appeared to be amorphous calcification rather than true osseous bridging. In conclusion, in view of the findings in this series, the opinion might be expressed that in four cases adequate fusion existed, and that surgical fusion was not indicated under any circumstances. The fact that tuberculous disease of the spine is not necessarily cured by fusion, whether spontaneous or surgical, is well recognized.

The fact that sinuses developed from the tuberculous abscess in several of these five patients, must not be misinterpreted as having a relationship to the bony bridging. In each instance, the bony bridging seen on the roentgenogram preceded the formation of a sinus. In this series a rather larger perifocal abscess occurred. It is conceivable that the abscess produced the irritation or inflammation in the ligamentous structures about the lesion, and thereby indirectly was the cause of the new-bone formation in the ligamentous capsular structures. As the sinus formation followed the bridging process, the possibility of secondary infection playing a rôle in the bridging must be excluded.

CONCLUSIONS

1. In a series of five cases of tuberculosis of the spine, four showed osseous bridging of vertebral bodies.

2. The fifth case showed abortive bony bridging which could not be considered to be actual spontaneous fusion.

3. The process described probably represents a reaction to irritation,

with periosteal new-bone formation or ossification in ligamentous tissue, and is not evidence of a healing process.

4. In certain instances such bony bridging accomplishes fusion of vertebrae involved by tuberculosis as effectively as posterior surgical fusion.

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TRANSILIAC AMPUTATION *

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In 1939, a fifteen-year-old boy was brought to this Hospital with a large sarcomatous tumor arising from the lesser trochanter and filling all the space between the trochanter and the tuberosity of the ischium. Disarticulation of the extremity at the hip joint was obviously impossible, and the tumor, not being radio-sensitive, grew to tremendous proportions. Finally, a pathological fracture developed, and his last few months were painful and miserable beyond description.

This experience convinced the authors that in such a case some effort should be made to eradicate the tumor, however drastic the operative procedure, or how little the chance for success. In order to do this, a radical removal of the lower extremity above the hip joint would be necessary (Fig. 1).

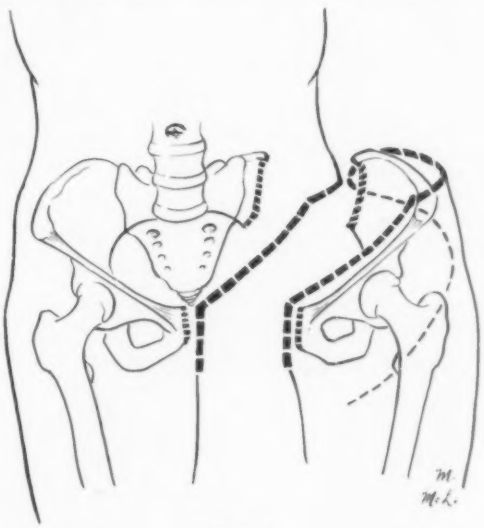

FIG. 1

Showing the regions at which the innominate bone is detached from the pelvis. This operation has been called interinnomino-abdominal amputation, interilio-abdominal amputation, transpubic amputation, transiliac amputation, transsacral amputation, transsacro-iliac amputation, hemipelvectomy, hindquarter amputation, transpelvic amputation, hemipelvic amputation.
▬▬ Anterior incision.
▪▪▪▪ Bone incision.
– – – – Posterior incision.

Since the operation is carried out between the peritoneum and the innominate bone it is referred to as interinnomino-abdominal, or interilio-abdominal amputation. Hindquarter resection, transpelvic amputation, hemipelvectomy, and transiliac amputation are some of the various names applied to the operative procedure. The more readily said and more easily understandable "Transiliac Amputation" will be used in this paper. According to Kocher, Billroth performed the first operation of this type in 1889.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 19, 1943.

In the ensuing fifty-four years, about 110 cases have been reported, with an operative mortality of approximately 60 per cent. The best article on this subject is one by Taylor and Wiles. In a thorough search through the literature they found seventy-nine reported cases to which they added five new cases. In 1940, Gordon-Taylor, in another article, reported an additional six operations, so that his experience with eleven cases is the most outstanding and unique of any yet recorded. In his series of eleven cases, there were four operative deaths,—a mortality of 36 per cent. There are but few cases reported by American surgeons, the best series being that of Leighton who has performed the operation successfully on three occasions.

The indications for such a radical amputation will always remain very limited. Over 90 per cent. of the operations reported in the literature have been done for malignant tumors affecting the proximal portion of the thigh, hip, or innominate bone, so that removal by disarticulation at the hip joint was impossible. Less than 10 per cent. have been for chronic disease affecting the hip joint or its environs, which has failed to respond to conservative

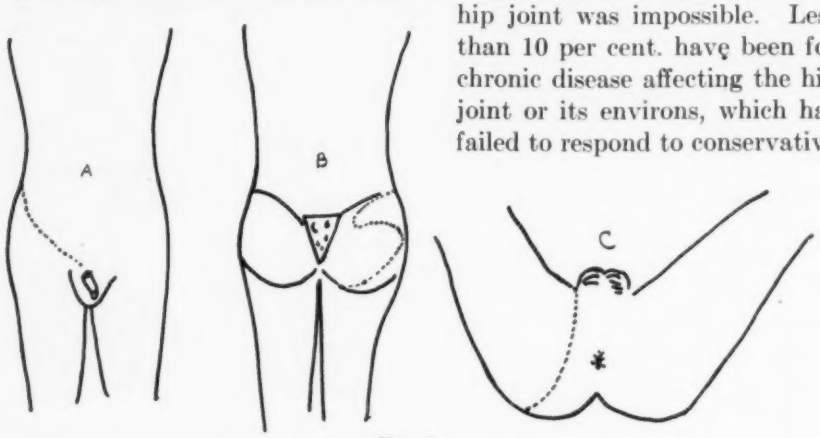

FIG. 2

A: Incision for anterior portion of operation.
B: Incision for posterior portion of operation.
C: Incision for perineal portion of operation.

treatment,—such as tuberculosis or osteomyelitis. It is possible that an occasional war casualty, such as a crushing injury of the upper thigh or hip region with gas infection, might extend the field of usefulness of this operative procedure.

In preparation for the operation, the lower bowel is cleansed by enema on the morning of the operation, and the bladder is catheterized in the operating room. It is absolutely essential that the patient's blood be typed, and that 1,000 cubic centimeters of blood be available in the operating room.

The operation is carried out with the patient in the full lateral position, but, before making the incision, *it is well for the surgeon himself to see that a large bore needle is securely placed in a satisfactory vein and that the blood transfusion can be carried out without further intervention.*

This simple precautionary measure will save much valuable time and temper during the execution of the operation. If possible the blood in the leg to be removed is saved by elevation and the application of a tight compression bandage.

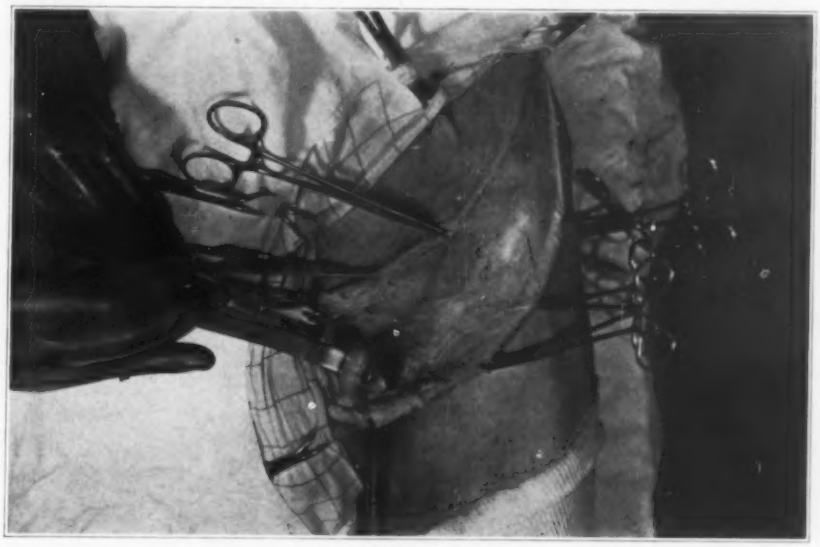

FIG. 3-A

Showing incision along the crest of the ilium and inguinal ligament, with retractor under the cord.

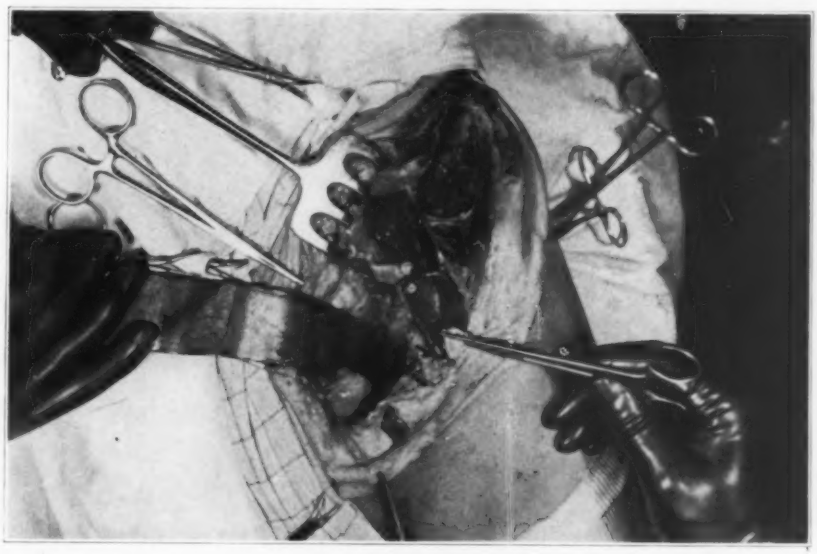

FIG. 3-B

Ribbon retractor is over bladder, the femoral artery and vein have been tied and cut, with the stumps lying over the psoas. A hemostat is on the distal stump of the femoral nerve, and a rake retractor holds flat abdominal muscles.

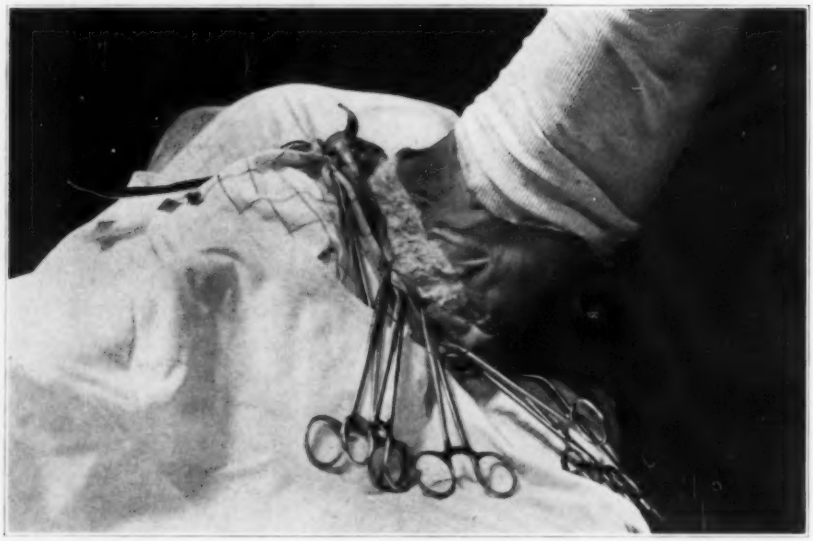

FIG. 4-A

With the leg abducted, the incision is made from the pubic tubercle downward and outward along the ischiopubic rami to the ischial tuberosity. The cord is in the retractor.

FIG. 4-B

Perineal muscles have been elevated from the rami; the symphysis pubis is being divided.

OPERATIVE TECHNIQUE

The operative technique may have to be modified somewhat to meet the requirements of the individual case. The operation falls naturally into three parts: anterior, perineal, and posterior (Fig. 2).

Anterior Portion.—For the anterior portion, the incision begins at the pubic tubercle, extends upward and outward along the inguinal ligament

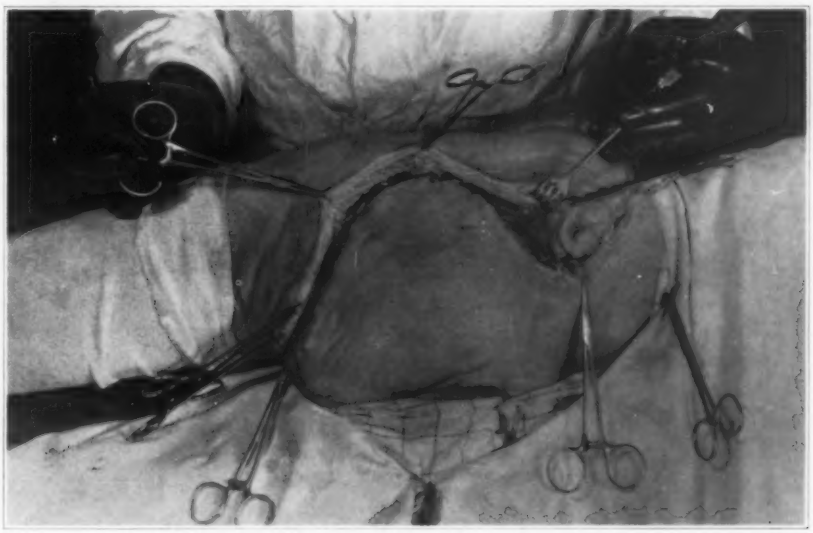

FIG. 5-A

The incision extends along the posterior crest of the ilium to the posterior spine, forward over the greater trochanter, and arches backward to the gluteal crease.

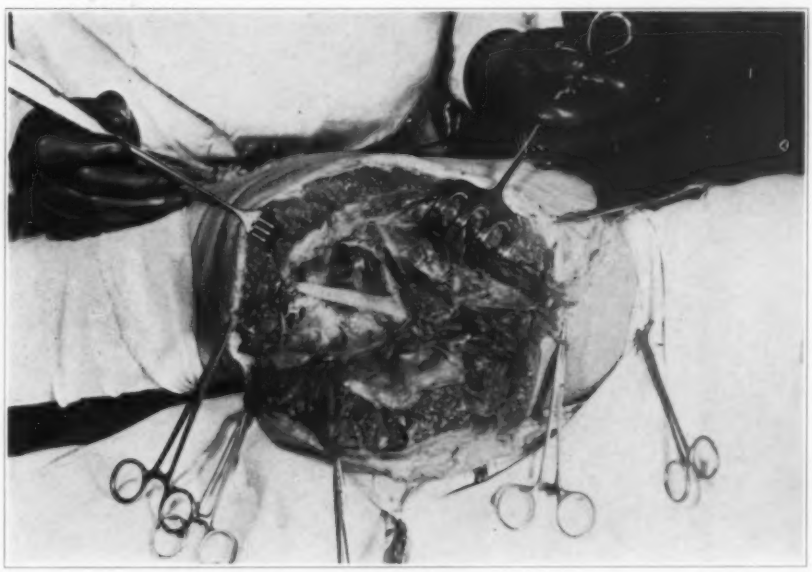

FIG. 5-B

Superior and inferior edges of gluteus maximus are exposed. The gluteus maximus aponeurosis has been cut at the level of the trochanter. The whole gluteus maximus has been turned backward as a flap. The piriformis and sciatic nerve are visible in the center of the wound.

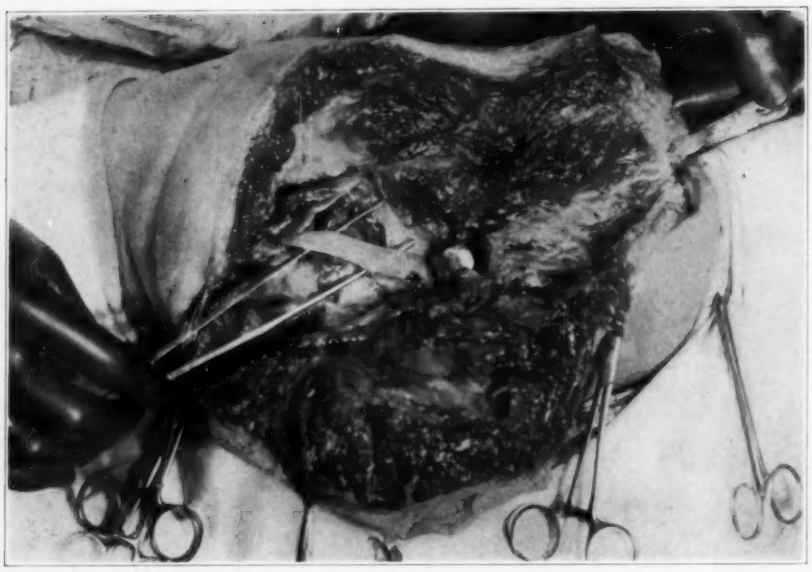

FIG. 6-A

Forceps are passed under sciatic nerve retractor through the greater sciatic notch into the pelvis, and out above the crest of the ilium. This indicates the line of the saw cut. (See text.)

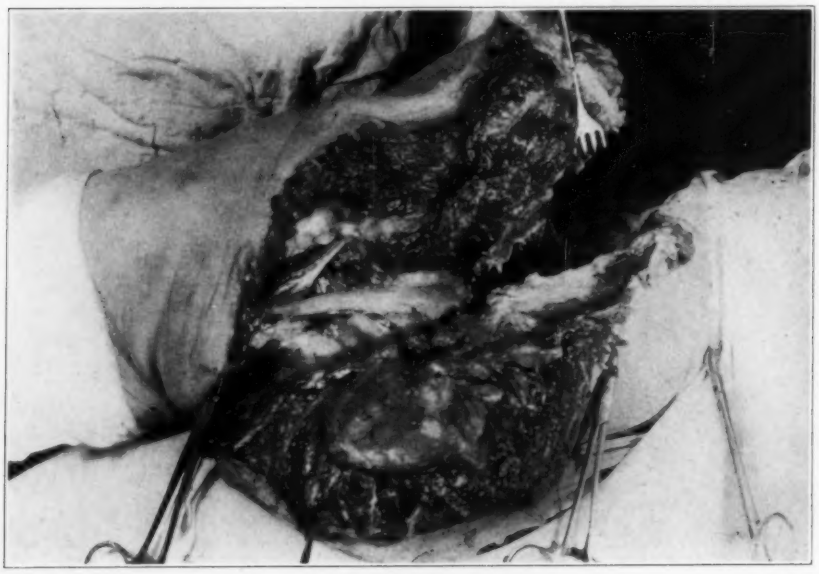

FIG. 6-B

The ilium has been divided. Since the symphysis has been divided in front, the innominate bone can be externally rotated so as to give a good exposure of the interior of the pelvis. (See Fig. 7-A.)

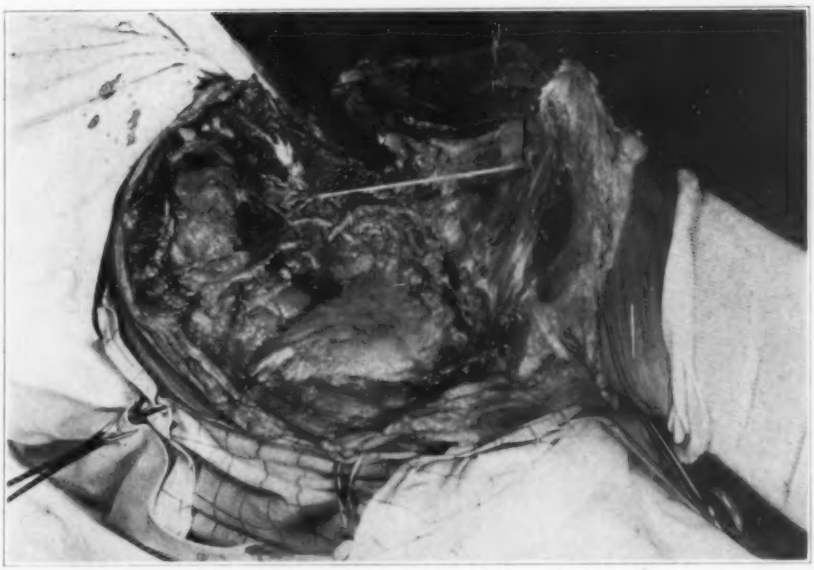

FIG. 7-A

Anterior view looking into pelvis after the symphysis pubis has been divided in front and the ilium has been divided behind. Stretched across the upper half of the wound is the obturator nerve. The top right-hand corner shows the pubis, and the lower center shows the bladder.

FIG. 7-B

The innominate bone and lower extremity have been removed, and the wound is ready for closure. In the upper left, a retractor holds the cord; in the direct center is the bladder; in the lower half is the gluteal flap.

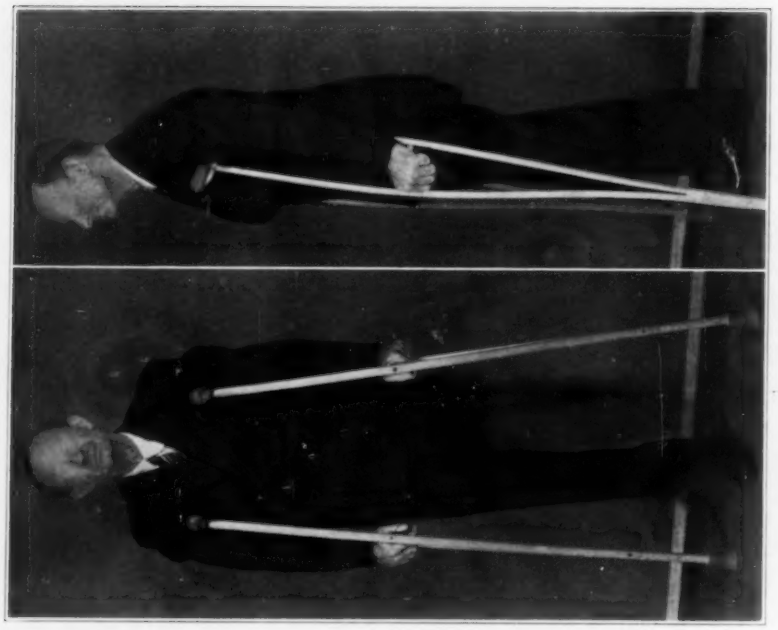

FIG. 8-B
The patient three months later.

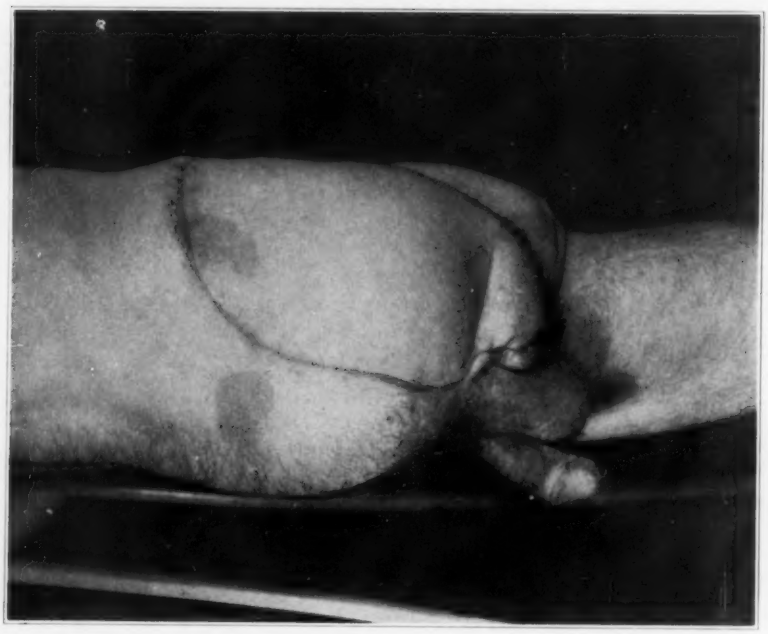

FIG. 8-A
Case 3. Showing scar following transiliac amputation.

to the anterior superior iliac spine and posteriorly along the iliac crest (Fig. 3-A). The abdominal muscles and inguinal ligament are detached from the iliac crest, and the iliac fossa is opened between the peritoneum and iliacus. At the pubis, the inguinal ligament and the rectus abdominis tendon are severed, the cord is retracted medially, the space of Retzius is opened, and the bladder is retracted into the pelvis (Fig. 3-B). The external iliac artery, vein, and femoral nerves are now located, tied, and cut. In the first three transiliac amputations, in addition to tying off the external iliac vessels, the common iliacs were exposed, and a rubber-shod arterial clamp was applied and later removed at the close of the operation. This was done with the idea of controlling hemorrhage from the branches of the external iliac artery. In the last three cases, the arterial clamp has not been used and it is believed it is not really necessary. This anterior wound is now tightly packed with dry gauze.

Perineal Portion.—The extremity is now widely abducted and the incision is carried downward and outward from the pubic tubercle, along the pubic and ischial rami to the ischial tuberosity (Figs. 4-A and 4-B). The subcutaneous rami are quickly exposed and the ischio cavernosis and transversus perinei are elevated subperiosteally from their inferior surfaces. An osteotome is now used to divide the ligaments and fibrocartilage of the symphysial synchondrosis.

Posterior Portion.—The incision over the iliac crest is carried posteriorly to the posterior superior iliac spine, where it is turned abruptly outward to the greater trochanter, and is arched backward and downward into the gluteal crease which it follows into the perineum to join the perineal portion of the incision (Figs. 5-A and 5-B). The posterior and inferior edges of the gluteus maximus are exposed, and its aponeurosis is cut in the same curve as the skin; the muscle is elevated so that a large flap of skin, fat, and gluteus maximus is fashioned. On retracting this flap, the gluteus medius and rotator muscles of the hip, and sciatic nerve are brought into full view. The piriformis is severed, and a tie is placed around the sciatic nerve before dividing it. A wire saw is now passed into the pelvis through the greater sciatic notch and is brought out of the pelvis over the iliac crest just in front of the sacro-iliac joint (Figs. 6-A and 6-B). The ilium is sawed through, and finally the sacrotuberous and sacrospinous ligaments are severed. The innominate bone is now quite movable, so that it rotates externally with the extremity, thus giving wide intrapelvic exposure (Fig. 7-A). After ligating and dividing the obturator vessels and nerve, the psoas is cut at the level of the sacro-iliac joint. Finally the levator ani is severed close to its origin on the pelvic surface of the pubic bone, and thus the innominate bone and lower extremity are completely free (Fig. 7-B). Closure is accomplished by drawing the gluteus maximus flap forward, and suturing it to the rectus abdominis, the lateral abdominal, the quadratus lumborum, and the psoas muscles. The skin sutures are loosely placed over three or four soft rubber drains, which remain for forty-eight to seventy-two hours.

FIG. 9-A

Case 4. Showing a large tumor in the thigh, buttock, and iliac fossa. Note the dilated subcutaneous veins.

FIG. 9-B

Three months after operation.

After the operation, the patients have been encouraged to turn and move about in bed as soon as their general condition permits. All patients in this series have had to be catheterized for two or three days following the operation, and during this immediate postoperative period, they have all exhibited a markedly apprehensive mental condition. Morphine sulfate in half-grain doses has been necessary in two cases during the first two postoperative days. Liquid diet for a week relieves the necessity for bowel movement, which might soil the perineal wound.

This operation, modified to meet individual requirements, has been used on six occasions. In every case, the diagnosis was sarcoma. There was one operative death,—a mortality rate of 16.7 per cent. This was in a patient whose thigh sarcoma had reached such tremendous proportions that it ruptured spontaneously to the exterior, and a fulminating and extensive gas-bacillus infection brought him to the surgery as an emergency.

CASE HISTORIES

CASE 1. A. B., a forty-five-year-old man, entered the Hospital April 8, 1940, complaining of pain in the left trochanteric area with sciatic radiation, of eight weeks' duration. He had lost fifteen pounds. On clinical examination, a definite thickening could be felt in the soft tissues at the attachment of the vastus lateralis just below the trochanter. Roentgenograms showed a destructive lesion with new-bone formation out from the lesser trochanter toward the ischial tuberosity. A biopsy, performed April 15, 1940, revealed sarcoma, and on April 22, 1940, the amputation was done, with 1500 cubic centimeters of citrated blood being given during the operation. Aside from temporary urinary retention the postoperative convalescence was uneventful. He died October 24, 1940, of pulmonary metastases.

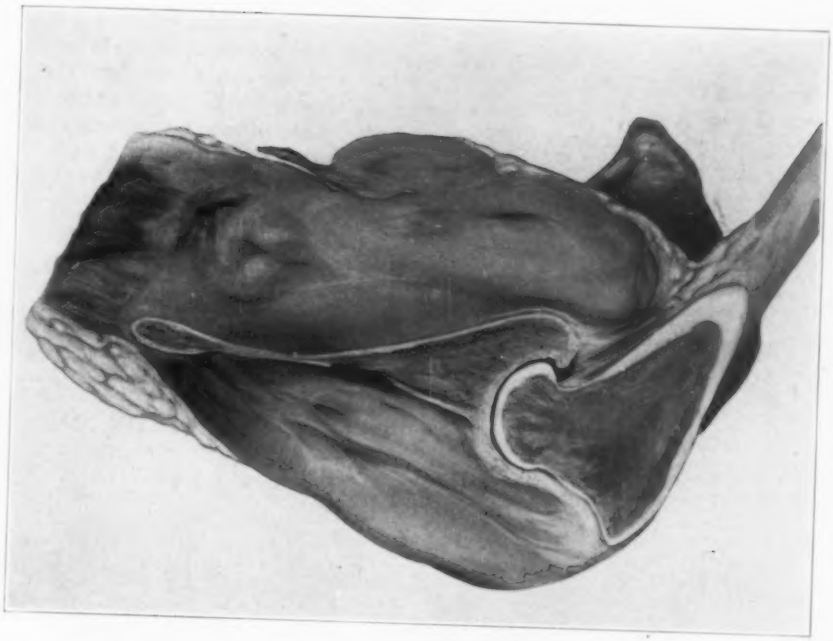

FIG. 9-D

Frontal section through tumor shows large mass of tumor external to the ilium.

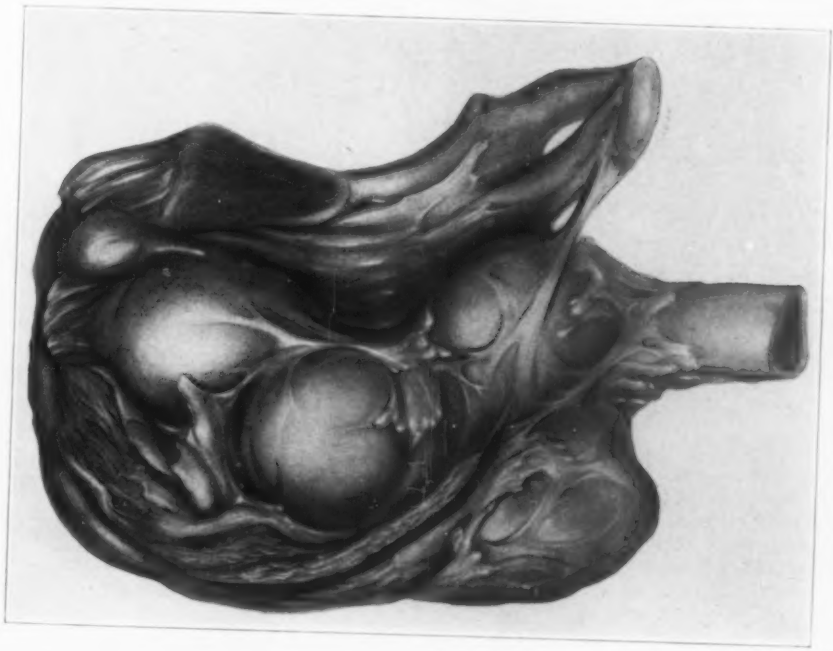

FIG. 9-C

The specimen after muscles had been dissected off. Note the tumor under the inguinal ligament, filling the entire iliac fossa.

CASE 2. C.D., a white male, was seen June 12, 1940, with large tumor mass under the gluteal muscles between the trochanter and the iliac crest of the left hip. Roentgenograms revealed an extensive destruction of the ilium just above the hip joint, with little, if any, new-bone formation. Laboratory results were irrelevant. No evidence was found of regional or remote metastases. On June 18, 1940, a biopsy specimen was taken, and a diagnosis of fibro-spindle-cell (oat-cell type) sarcoma was made. On June 27, 1940, a radical transiliac amputation was performed, 1500 cubic centimeters of citrated blood being given during the operation. The postoperative convalescence was uneventful except for temporary urinary retention, necessitating catheterization for two days. Six months later, he died without much suffering from pulmonary metastases.

CASE 3. G. H., aged fifty-one, entered the Neurological Service February 23, 1942, complaining of pain in the left thigh of six months' duration. There was no familial history of malignancy. Pain, first noted in the left hip region on occasion of a light blow in that area in September 1941, had slowly increased in the lateral aspect of the hip and down the thigh. This had been an almost constant soreness, sometimes with knifelike stabs. More recently there had been much pain in the lower part of the buttock. There had been no numbness, but patient had had increasing weakness of the leg. Weight loss had amounted to thirty-three pounds since the onset of pain. There was some fibrillary twitchings of the leg, and atrophy of three centimeters in the circumference at mid-thigh. The condition was thought to be a neurological affliction.

Physical examination revealed that the left hip was held in thirty degrees of flexion,

FIG. 10-A FIG. 10-B

Fig. 10-A: Case 5. Posterior view shows a large chondromyxosarcoma of the thigh.

Fig. 10-B: Lateral view. Note the large nodules of tumor. There is considerable oedema below the knee, and a dorsiflexor paralysis of the foot.

with considerable muscle spasm about the hip. Any attempted active or passive motion was very painful. With the patient lying prone, there was noted an obliteration of the left gluteal fold, and a mass could be made out below and posterior to the greater trochanter. The left knee kick and the Achilles kick were greatly diminished.

Laboratory findings were irrelevant.

Roentgenograms show two irregularly oval areas of bone destruction at the upper end of the left femur, just below and including the lesser trochanter, with thinning of the cortex, and periosteal reaction over this area with extension of calcification into the soft tissues. No metastatic lesions were found in the chest, spine, or pelvis.

Preoperatively the patient received 500 cubic centimeters of citrated blood, and 500 cubic centimeters of normal saline.

On March 2, 1942, a biopsy was done followed by transiliac amputation with cyclopropane anaesthesia. The biopsy report was osteolytic osteogenic sarcoma. Incision was made along the iliac crest with retroperitoneal dissection to expose the iliac vessels. An artery clamp was placed temporarily on the common iliac artery, and the external iliac was ligated. A large portion of the proximal gluteus maximus was preserved with its blood supply and overlying skin. Bone resection was accomplished by disarticulation at the symphysis pubis, by a vertical saw line with a Gigli saw from the greater sciatic notch upward through the ilium lateral to the sacroiliac joint. The inguinal ligament was preserved. The gluteal flap was sutured to the stump of the ilium and to the inguinal ligament. Eight hundred and fifty cubic centimeters of citrated blood and 500 cubic centimeters of 5-per-cent. glucose were given during the operation. Systolic pressure remained at 110 and above during the entire procedure, except for a slight transient drop as the sciatic nerve was sectioned,

FIG. 10-C

The specimen after removal of the leg and extraneous material, showing chondromyxosarcoma.

FIG. 11-A

Case 6. Roentgenogram of the hip taken in July 1942 just before the local excision was done.

despite previous infiltration with 2-per-cent.-procaine solution. Operative time (exclusive of biopsy) was three hours and forty-five minutes.

The postoperative course was good. Tincture of opium was given to control bowels for eight days. Patient was catheterized once only. A painful hemorrhoid developed, but patient had good sphincter control and active contraction of the levator ani and gluteus maximus. The wound healed well.

When last seen on January 10, 1943, there was no evidence of local or distant recurrence (Figs. 8-A and 8-B). The patient had returned to work as an attendant in a State Hospital six weeks after the operation.

CASE 4. E. F., a thirty-three-year-old Italian woman, entered Stanford Hospital March 12, 1942, complaining of a rapidly growing tumor mass in the right hip region of at least five months' duration.

She had had bilateral congenital dislocation of the hip, and had been treated for this condition from the time she was five until she was nine years old. She stated that there had always been considerable stiffness and a limp, especially on the right side.

Examination revealed a huge tumor mass beginning eight centimeters below the greater trochanter and extending above the iliac crest. The entire iliac fossa was filled with the tumor which could be felt to extend over to the mid-line of the abdomen. It was firmly attached to the innominate bone (Fig. 9-A). Both hip joints showed a marked limitation of motion.

Roentgenograms revealed a large tumor with considerable destruction of the ilium.

The patient was operated upon March 16, 1942. A blood transfusion of 500 cubic centimeters had been given the day before. The operative procedure was carried out with great difficulty because of the extreme size of the tumor. To avoid opening the tumor, it was necessary to resect a portion of the peritoneum and a small part of the attachment of the abdominal muscles to the iliac crest. Lymph nodes along the iliac crest appeared to be involved and were removed.

The operating time was four hours and forty minutes.

CASE 5. I. J., female, fifty years old, entered Stanford Hospital June 11, 1942, complaining of a tumor of the thigh. The family history and past history were irrelevant. About January 1939, she had noted a tumor mass in the lateral aspect of the right thigh. This grew slowly and was not painful. In January 1940, a local excision of the tumor was done by her family physician. Eleven months later she noted a local recurrence of the tumor, and in February 1941, the tumor was again excised. In September 1941, the tumor again recurred and had grown quite rapidly ever since.

Examination revealed a tremendous firm tumor affecting the entire length of the right thigh. Large orange-sized nodules projected posteriorly and medially (Figs. 10-A

and 10-B). Over the tumor were two long scars from the previous operations. She walked with great difficulty because of the weight and interference with joint and muscle function, but also because of a flaccid paralysis of the dorsiflexor muscles of the foot. Sensation in the foot was impaired.

Sections of the tumor obtained from the material removed at the first two operations showed a typical chondromyxosarcoma.

Roentgenograms showed no evidence of bone involvement or metastases.

On June 12, 1942, a right transiliac amputation was performed, 1500 cubic centimeters of citrated blood being given during the two-hour operation. Her general condition remained good throughout. During the first three postoperative days she was quite apprehensive. Catheterization was necessary. Otherwise, her course was uneventful.

In December 1942, she remained quite well.

CASE 6. K. L., male, aged twenty-four, was brought by ambulance to Stanford Hospital on October 20, 1942, as an emergency case because of gas-bacillus infection in the left thigh. The patient had had "pains" in the left hip region and "sciatica" off and on for four years. In January 1942, he had noticed a swelling just below the left inguinal ligament. In April 1942, the pain and swelling had disabled him and he had taken to his bed. In July 1942, an extensive local excision of a tumor was done, and it proved to be a sarcoma. A series of roentgen-ray treatments were given, but in spite of this the thigh continued to increase in size, and continuous use of morphia was necessary for pain.

Finally on October 15, 1942, the huge tumor ruptured spontaneously about four inches below the anterior superior iliac spine. Two days later the temperature rose to 104 degrees Fahrenheit, the patient became very toxic, and he was brought to the Hospital.

Examination revealed that the patient, who had been confined to bed for six months,

FIG. 11-B

Roentgenographic appearance on entry to the authors' Service on October 1942. Note the destruction of the bone, and the gas in the tissues.

was extremely ill, toxic, and feverish. He was generally emaciated, and there were pressure sores over the sacrum. The left lower extremity was tremendously swollen, and lay in a position of complete external rotation with the knee flexed and the foot in equinus. Crepitus was present from the inguinal ligament to the knee. About four inches below the anterior superior spine and in the proximal end of the old surgical scar there was a ragged hole, one inch in diameter. Foul smelling brownish fluid and chunks of necrotic tumor bubbled out of the wound with many gas bubbles.

Smears from the fluid showed many gram-positive rodlike bacilli, and cultures were subsequently reported strongly positive for gas bacilli. Hemoglobin was 52 per cent. Sahli; and there were 36,000 leukocytes.

Roentgenograms revealed a destructive lesion in the intertrochanteric area, impending pathological fracture, and much gas in the tissues (Fig. 11-B).

After preliminary transfusion, a transiliac amputation was done according to the technique described. One thousand cubic centimeters of blood was given during the

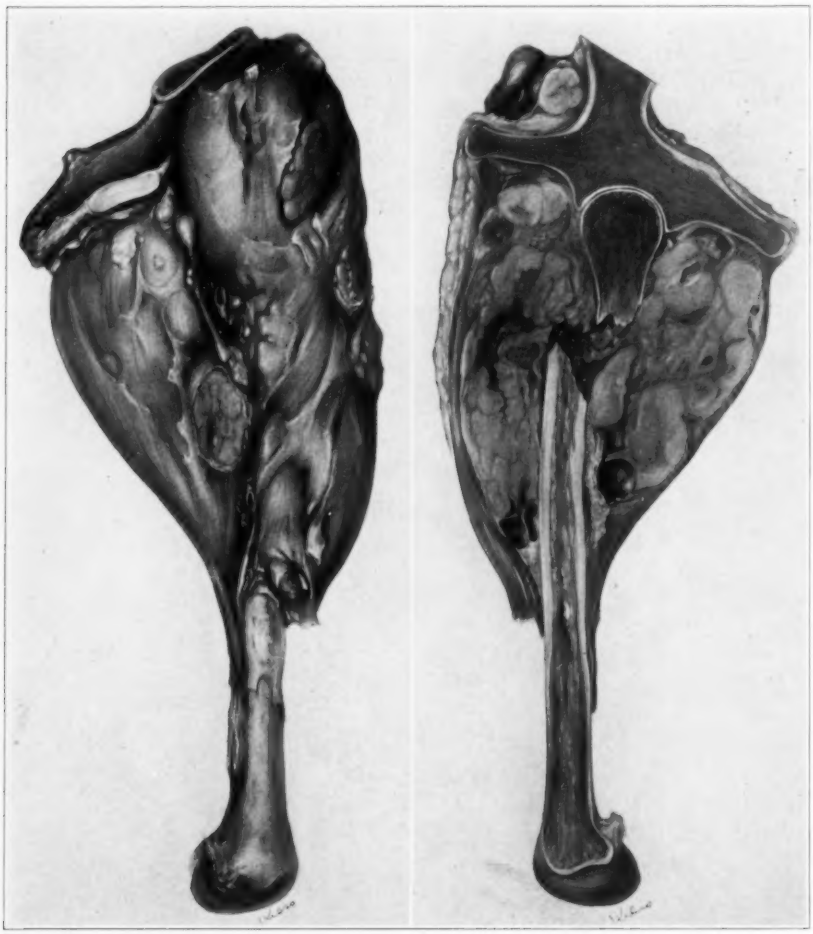

FIG. 11-C FIG. 11-D

Fig. 11-C: The innominate bone, femur, and large sarcoma after the leg and overlying muscles had been removed.

Fig. 11-D: Saggital section through specimen. The pathological fracture occurred at operation. Tumor contains much gas from gas-bacillus infection.

operation, and 500 cubic centimeters shortly thereafter. The operative time was three hours. His condition was poor throughout, and he died four hours after returning to the ward.

CONCLUSIONS

The basic operative technique for transiliac or interinnomino-abdominal amputation has been performed by one of us (D. K.) six times, with one operative death, — a mortality rate of 16.7 per cent. In reviewing this experience two points seem particularly important for any who may be called upon to do this stupendous eradication. First, the surgeon must so fortify his anatomical knowledge that he can perform the operation without hesitancy. Second, he must satisfy himself that the patient is receiving blood as the operation is being carried out.

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TREATMENT OF COMPLETE PERMANENT ACROMIO-CLAVICULAR DISLOCATION BY SURGICAL ARTHRODESIS

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The need for surgical treatment of symptomatic complete permanent acromioclavicular dislocation is well recognized. Many methods of surgical restitution of complete disruption of this joint and its ligaments have been devised and recommended; but practically all of these operations are only modifications of the one described by Watkins in 1925, and are based upon one principle,—namely, the restoration or replacement of the acromioclavicular and coracoclavicular ligaments by silk, wire, or fascial strips. In the hands of many surgeons, operations of this type have failed to give completely satisfactory results because of failure of the reconstructed ligaments (particularly those of fascia) to maintain reduction or, most commonly, because of persistent pain which has been interpreted by most observers to be due to arthritic changes in the acromioclavicular joint.

"Based upon the premise that a stable shoulder with full function and with absence of pain is consistent with a loss of continuity in the shaft of the clavicle", Mumford resected the distal end of the clavicle and reported good results in four patients with chronic subluxation and partial dislocation of the acromioclavicular joint.[1] However, this operation was not done on any patient with complete permanent dislocation, for which condition Mumford advised fascial suture of the coracoid and clavicle.

During the last year and a half, three soldiers have been admitted to the Orthopaedic Service of this Hospital, because of disabling complete permanent acromioclavicular dislocation. All three complained of pain, weakness of the shoulder under heavy stress, and inability to carry a pack or rifle because of pain incident to pressure of the pack strap or rifle upon the upward riding clavicle. Because of the soldier's strenuous physical activity under many and varied conditions, it was felt that, in order to render the soldier fit for full military duty, any treatment to correct this disability must fulfill three essential requirements:

1. The shoulder must be absolutely stable under any type of stress;
2. It must be painless under all conditions;
3. There must be no serious impairment of motion.

Resection of the distal end of the clavicle could not meet all of these requirements since upward riding of the clavicle would not be eliminated and absolute stability would not be attained. Complete failure of fascial repair of the ligaments in the first case prompted an attempt at surgical fusion of the acromioclavicular joint. It was felt that this would certainly accomplish absolute stability and eliminate pain. In spite of the fact that

limitation of motion has been reported with fixation of this joint by repair with wire or silk ligament, and that it is the general opinion that acromioclavicular arthrodesis would be disabling, it was believed that fusion of this joint would not produce serious impairment of motion, or disability. Surgical fusion of the acromioclavicular joint has now been carried out on three patients; and, although this report may be premature, it is felt that sufficient time has elapsed to show the results in two cases. The third patient has only recently been operated upon, and it is hoped subsequently to report the results in this case.

The operation is simple, and presents no technical difficulties. The acromioclavicular joint is exposed through an anterior curved incision, a flap being reflected posteriorly to expose the distal end of the clavicle and the acromion. All articular cartilage is completely removed from the opposing joint surfaces, and the raw bone surfaces are brought into apposition and secured by a vitallium screw driven from the tip of the acromion through the acromion and into the cortex of the clavicle. Internal fixation is considered necessary to maintain complete immobilization of the joint while fusion is taking place. Small bone chips are raised from the adjacent clavicle and acromion, and are packed in and around the joint surfaces. In the second case, internal fixation was obtained by two Kirschner wires. Immobilization was maintained as noted in the following case reports.

FIG. 1-A

Case 1. Roentgenogram of the left acromioclavicular joint twelve months after operation. The vitallium screw is still in place.

CASE 1. M. K., male, aged twenty-eight, was admitted to the Hospital on May 1, 1941, complaining of pain in the left shoulder, weakness, and inability to lift heavy objects, and inability to carry a pack. The patient stated that on or about January 1, 1941, he was thrown from a horse, striking directly on the left shoulder. There was immediate severe pain and disability, and soon after the injury he noticed a "lump over the left shoulder". Symptoms persisted, but the patient did not report to his Medical Officer until the day before admission to the Hospital.

Examination revealed a stocky white male with unusually well-developed musculature. The general physical examination was negative except for the left shoulder. There was a complete dislocation of the left acromioclavicular joint with the distal end of the clavicle displaced upward. The dislocation was easily reduced manually, but recurred immediately after removal of upward pressure. Motion in the shoulder joint was full and free. Roentgenograms confirmed the diagnosis of permanent, complete acromioclavicular dislocation.

On May 5, 1941, the acromioclavicular and coracoclavicular ligaments were repaired by the Watkins technique using three-eighths-inch strips of fascia lata. The shoulder was immobilized by means of adhesive strapping and a Velpeau bandage. He was discharged to duty on June 27, 1941, with a stable acromioclavicular joint throughout, and a full range of motion in the left shoulder except in abduction which was limited to 165 degrees. He was symptom free.

On August 10, 1941, while lifting a bale of hay from the floor, the patient felt "something tear" in his left shoulder. This was accompanied by severe pain and disability,

FIG. 1-B

Shoulder contour one year after operation.

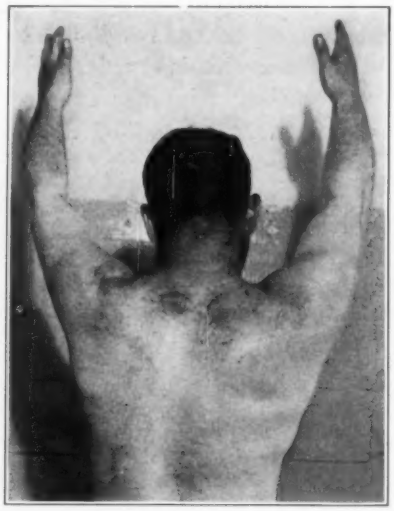

FIG. 1-C

Abduction one year after operation.

FIG. 1-D

External rotation one year after operation.

and he was readmitted to the Hospital the following day. Examination revealed complete dislocation of the left acromioclavicular joint with considerable swelling and ecchymosis.

On August 25, 1941, the acromioclavicular joint was exposed through the old incision. The fascial sutures were found to be frayed and completely torn. Acromioclavicular fusion was carried out as described, and the arm and shoulder were immobilized by a Velpeau bandage for eleven weeks, after which time physiotherapy and active exercises were started. Roentgenograms at this time showed evidence of fusion at the acromioclavicular joint. The patient was discharged to duty on December 19, 1941. The acromioclavicular joint was stable and the patient was symptom free. Scapulohumeral abduction was limited at 80 degrees and total abduction was limited at 165 degrees.

FIG. 1-E

Internal rotation one year after operation.

On August 20, 1942, he stated that his shoulder had not "bothered" him. He had been doing full field duty in a mechanized cavalry unit without pain or symptoms in the left shoulder, and had recently completed a twenty-five-mile hike with full pack and equipment. In addition to his regular duties, he had been acting as instructor in swimming and lifesaving.

The left acromioclavicular joint was clinically solid. External rotation, internal rotation, flexion, and extension of the left shoulder were full. Scapulohumeral abduction was limited at 80 degrees, and total abduction was limited at 165 degrees.

Limitation of abduction was believed to be due to two factors: a small bone spur at the tip of the acromion limiting scapulohumeral abduction, and incomplete rotation of the scapula limiting total abduction. It was noted that full abduction of the right arm was difficult, and that the right scapula did not rotate fully. Full abduction could be accomplished passively with no discomfort to the patient.

CASE 2. R. L. F., male, aged twenty-four years, was admitted to the Hospital on November 30, 1941, complaining of pain in the right shoulder, inability to lift heavy objects or to carry a pack. About one month before admission he had been thrown from a motorcycle a distance of about ten feet, striking directly on his right shoulder. Pain and disability had persisted from the time of injury.

On examination, there was a complete dislocation of the right acromioclavicular joint with the distal end of the clavicle displaced upward about one inch. The general physical examination was essentially negative. Roentgenograms confirmed the diagnosis. The dislocation could be easily reduced, but recurred immediately when pressure was released.

Because of the relatively short duration of the dislocation, it was felt that conservative treatment should be given a trial. The dislocation was reduced and reduction was maintained by adhesive strapping and a Velpeau bandage. Immobilization was maintained for six weeks, but, on removal of the dressing, complete dislocation immediately recurred.

On January 1, 1942, fusion of the acromioclavicular joint was done, and the shoulder was immobilized by adhesive strapping and a Velpeau bandage. On the seventeenth day

FIG. 2-A

Case 2. Roentgenogram of right acromioclavicular joint five months after operation. Kirschner wires have been removed.

after operation, the patient complained for the first time of severe pain in the right shoulder. He denied trauma. Examination revealed an apparent recurrence of the dislocation. Roentgenograms showed complete dislocation with the vitallium screw retained in the distal end of the clavicle, but not in contact with the acromion.

On February 12, 1942, the acromioclavicular joint was exposed through the old incision. The vitallium screw was found to have broken through the upper shelf of the acromion. The screw was removed, and reduction and fusion were again carried out, using two Kirschner wires traversing the acromion into the distal end of the clavicle for internal fixation. A shoulder spica was applied with the arm in 90 degrees' abduction.

He was transferred to a general hospital three weeks after operation and was not seen again until July 11, 1942. He stated that the cast had been removed nine weeks after the operation, and that the Kirschner wires were removed two weeks later. He had been discharged to duty fifteen weeks after operation, and had been doing full field duty in a mechanized cavalry unit; he was entirely symptom free.

On examination, there was normal contour of the right shoulder. The acro-

FIG. 2-B

Degree of abduction six months after operation.

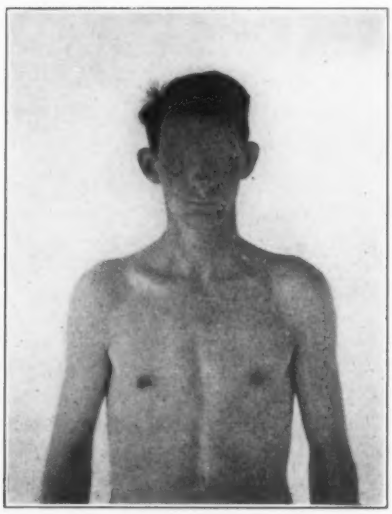

FIG. 2-C

Shoulder contour six months after operation.

FIG. 2-D

External rotation six months after operation.

mioclavicular joint was clinically solid, and there was a full free range of active and passive motion of the right shoulder in all planes. Roentgenograms showed firm bony arthrodesis of the acromioclavicular joint.

FIG. 2-E

Internal rotation six months after operation.

COMMENT

The accompanying photographs show the range of motion present in both of the cases reported. Several factors might be considered to explain the limitation of abduction present in Case 1:

1. Prolonged immobilization in adduction with resultant periarticular fibrosis and adhesions.

2. Spur formation at the tip of the acromion, limiting scapulohumeral abduction.

3. Failure of complete rotation of the scapula, limiting total abduction.

(A similar difficulty in complete scapular rotation was noted in the normal right shoulder.)

These explanations are not offered with any intent to prove or suggest that limitation of abduction was not due primarily to arthrodesis of the acromioclavicular joint, but it should be recognized that other factors may be present to explain, at least partially, the limitation of motion.

Both patients are symptom free, the shoulders are stable under con-

ditions of unusually strenuous physical activity, and in neither patient is there disabling impairment of motion. The three essential requirements have been fulfilled.

CONCLUSION

1. Surgical arthrodesis of the acromioclavicular joint is feasible, the operation is not extensive, and presents no technical difficulties.

2. This procedure has given entirely satisfactory results in two cases, and is presented for consideration and evaluation by other surgeons.

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CALCIFICATION AND OSSIFICATION

IV. The Healing of Fractures in Man under Clinical Conditions * †

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I. INTRODUCTION

This report presents direct observations of bone repair as it occurs in man under clinical conditions following reduction, and in the course of immobilization by the various procedures of classic orthopaedic treatment. Selected from 133 cases of various fractures treated by open reduction, forty-eight cases are described as sources of material upon which studies have been made of the calcification and the microscopic

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† This work was aided by a grant from the Josiah Macy, Jr. Foundation.

anatomy of the normal human callus. The remaining eighty-five cases, still under investigation, were classified and were eliminated as examples of delayed union, non-union, and pathological fractures on the basis of:

1. Routine hospital history and physical examination;
2. Roentgenograms taken at various intervals as indicated by clinical treatment;
3. Laboratory findings on blood and urine, including levels of the serum calcium, inorganic phosphorus, and alkaline phosphatase activity;
4. Microscopic examination of the specimen of the callus excised at operation.

In more than 4000 papers dealing with the subject of the healing of fractures, published between the time of the writings of Galen and Hippocrates and the year 1940, the chief interest has been in the origin of the new bone and the factors influencing osteogenesis; and the principal method of study has been the observation of callus formation in experimental fractures in animals. Relatively little of this work may be considered systematic observation of bone repair in the human, although considerable discussion of the possible differences between bone regeneration of man and animals is found in the nineteenth century literature[94]. According to Hein, Gurlt, Fujinami, Maas, and others, callus formation in man is essentially the same as in laboratory animals, and differs only in certain obscure "minor species differences" [30]. Stanley, Paget, Hein, and Koch, however, stated that, in fractures in animals, healing is accomplished with a smaller amount of new-bone formation than is ordinarily seen in man, although it was recognized that just as well-approximated wounds heal more rapidly and with less scar, so also do well-reduced fractures heal with less callus, and unite more rapidly. Stanley argued, ". . . the condition of the surrounding soft parts [in animals] is so materially different from the condition of these parts preceding and accompanying the death of the shaft of a bone in man, that, in consequence, the features of the reparative process in the two cases are essentially different. It has, therefore, been incorrectly assumed that because such is the reparative process of fracture or necrosis in animals, it must be so likewise in man." Notwithstanding the validity of this position as to differences in the nature of the injury in experimental and accidental fractures, no qualitative or specific differences have been recognized in the process of bone repair.

From the vast literature on healing fractures prior to 1886 reviewed by Bruns and between 1886 and 1939 by Block, and by many others for recent years, the following reports constitute the important works on fracture healing in the human. John Hunter, Curling, Ollier, Wolff, Bier[7], Macewen, and others have described gross specimens of various fractured bones at autopsy, from museum specimens, at operations, and in the clinical handling of exposed compound fractures. In essays, or in interpretations and illustrations appending experimental work, microscopic studies upon the formation of human callus are mentioned by

TABLE I

RÉSUMÉ OF CASES FROM WHICH SPECIMENS WERE OBTAINED AT OPEN OPERATION

Case No.	Age	Location of Fracture	No. of Days After Fracture	No. of Times Reduction Attempted	Type of Immobilization	Position of the main Fragments	Ambulatory or Hospitalized	Serum			Vitamin D[4]	Callus		
								Calcium[1]	Inorganic Phosphorus[2]	Phosphatase[3]		Microscopic Examination		X-Ray
												New Bone[5]	Osteoid[6]	Calcium Deposits[7]
101	10	Colles'	8 and 21	1	Cast	Angulation	Ambulatory	11.1	3.9	9.4	+	+	0+	+
104	34	Radius, head	6	0	Cast	Separation	Ambulatory	–	–	–	0	–	–	0
105	6	Tibia, middle third	30	1	Cast	Angulation	Ambulatory	10.8	4.2	7.1	0	+	0+	+
106	40	Radius, head	13	0	Cast	Separation	Ambulatory	12.1	3.2	3.1	0	?	?	0
107	52	Colles'	25	2	Cast	Angulation	Ambulatory	11.9	4.0	3.2	0	?	?	+
108	73	Ulna, olecranon	7	0	Cast	Comminution, separation	Ambulatory	9.8	3.5	2.1	0	?	?	0
109	87	Humerus, epiphyseal fracture-separation	5	1	Cast	Separation	Ambulatory	9.8	3.0	3.1	0	–	–	0
110	32	Humerus, middle third	4	1	Traction	Overriding	Hospitalized	10.3	3.3	3.1	0	–	–	0
111	72	Tibia, lower third	6	1	Cast	Angulation	Ambulatory	9.6	3.1	3.3	0	0	0	0
112	31	Tibia, lower third	4	0	Cast	Angulation	Hospitalized	9.4	3.8	4.1	0	0	0	0
113	18	Femur, upper third	88	1, Pin[8]	Traction	Reduction[9]	Hospitalized	9.9	4.6	4.2	0	+	+	+
116	53	Humerus, supracondyle	14	1	Cast	Comminution, separation	Hospitalized	8.7	5.0	10.5	0	?	?	0
117	20	Femur, middle third	95	1, Pin[8]	Traction	Overriding, separation	Hospitalized	9.9	4.4	2.7	0	+	+	+
118	37	Humerus, supracondyle	4	1	Cast	Comminution, angulation	Hospitalized	10.0	3.7	2.5	0	?	?	0
123	6	Humerus, lateral epicondyle	3	1	Cast	Separation	Ambulatory	11.1	5.2	4.6	0	?	?	0
125	14	Femur, upper third	10	1	Traction	Angulation	Hospitalized	10.5	5.4	–	0	0	0	0

TABLE I — (*Continued*)

RÉSUMÉ OF CASES FROM WHICH SPECIMENS WERE OBTAINED AT OPEN OPERATION

Case No.	Age	Location of Fracture	No. of Days After Fracture	No. of Times Reduction Attempted	Type of Immobilization	Position of the main Fragments	Ambulatory or Hospitalized	Serum			Vitamin D[4]	Callus		
								Calcium[1]	Inorganic Phosphorus[2]	Phosphatase[3]		Microscopic Examination		X-Ray
												New Bone[5]	Osteoid[6]	Calcium Deposits[7]
127	14	Radius, shaft	11	3	Cast	Separation	Ambulatory	11.0	4.0	–	0	–	–	0
132	56	Tibia, lower third	14	1	Cast	Angulation	Hospitalized	9.0	4.9	3.3	0	?	?	0
134	10	Tibia, upper third	59	1	Cast	Angulation	Ambulatory	10.2	3.9	3.2	+	+	+	+
138	12	Femur, middle third	20	1	Traction	Reduction[9]	Hospitalized	9.9	4.5	8.3	0	+	++	0
139	21	Humerus, lateral epicondyle	2	1	Traction	Separation	Hospitalized	10.4	3.9	2.9	0	–	–	0
140	16	Humerus, epiphyseal fracture-separation	10	1	Cast	Overriding	Ambulatory	11.0	4.7	1.9	0	?	?	0
141	15	Femur, middle third	17	1, Pin[8]	Traction	Angulation, separation	Hospitalized	9.7	4.8	6.7	0	+	++	0
144	54	Femur, neck	8	0	Traction	Comminution, separation	Hospitalized	10.0	4.4	–	0	0	0	0
146	47	Tibia, upper third	5	0	Cast	Reduction[9]	Hospitalized	9.3	4.0	5.9	0	+	++++	0
147	19	Femur, middle third	19	0	Traction	Angulation, separation	Hospitalized	9.0	3.8	–	+	+	++++	0
148	23	Tibia, lower third	98	1, Pin[8]	Cast	Angulation	Hospitalized	9.5	4.7	–	+	+	0–+	+
149	41	Femur, middle third	18	0	Traction	Angulation, separation	Hospitalized	9.5	4.0	–	+	+	+	0
150	28	Femur, middle third	143	1	Traction	Separation	Hospitalized	9.5	3.5	–	+	+	0–+	+
151	20	Tibia, lower third	140	1, Pin[8]	Cast	Angulation	Hospitalized	9.0	4.9	–	–	–	0–+	+
154	33	Tibia, lower third	4	1	Cast	Angulation	Ambulatory	–	–	–	0	0	0	0
156	67	Ulna, olecranon	5	1	Cast	Separation	Ambulatory	8.7	3.9	3.0	0	?	?	0
164	11	Clavicle	9	1	Cast	Angulation	Ambulatory	10.2	3.2	2.0	0	+	+	+
167	74	Humerus, lateral epicondyle	11	1	Traction	Separation	Hospitalized	10.1	4.0	3.7	0	?	?	0

168	44	Radius, head	2	0	Cast	Comminution, separation	Ambulatory	–	3.9	–	0	–	–	0
169	39	Radius, head	1	0	Cast	Separation	Ambulatory	–	–	–	0	–	–	0
170	58	Femur, middle third	55	0	Traction	Comminution, overriding	Hospitalized	9.3	3.9	–	0	+	+	+
177	17	Humerus, middle third	28	0	Traction	Overriding	Hospitalized	10.0	3.1	–	+	+	++	0
178	25	Tibia, lower third	48	1, Pin [8]	Cast	Overriding	Hospitalized	10.5	2.7	–	+	+	+	+
184	23	Femur, middle third	15	1, Pin [8]	Traction	Angulation	Hospitalized	10.0	3.8	6.9	+	0	0	0
188	15	Tibia, middle third	23	1, Pin [8]	Traction	Angulation	Hospitalized	10.0	4.8	8.1	0	+	+++	0–+
189	18	Tibia, middle third	28	1	Cast	Comminution, angulation	Hospitalized	10.5	4.4	6.8	0	+	+++	0–+
191	60	Radius, shaft	19	3	Cast	Overriding	Ambulatory	10.6	4.4	3.0	0	+	+++	+
192	16	Humerus,epiphyseal fracture-separation	3	1	Cast	Angulation	Ambulatory	10.0	3.1	2.5	+	–	–	0
193	67	Femur, lower third	12	1	Traction	Reduction [9]	Hospitalized	9.5	3.5	4.2	0	+	++++	0
198	24	Femur, middle third	18	0	Traction	Angulation, separation	Hospitalized	10.1	3.2	–	+	+	++++	0–+
200	24	Femur, neck	47	0	Traction	Separation	Hospitalized	10.2	3.0	–	+	+	+	+
233	21	Femur, middle third	33	1	Traction	Reduction [9]	Hospitalized	–	–	–	0	+	++	+

1. Calcium: Amount is shown in milligrams per 100 cubic centimeters of blood serum.
2. Inorganic phosphorus: Amount is shown in milligrams per 100 cubic centimeters of blood serum.
3. Phosphatase: Alkaline phosphatase activity is shown in Bodansky units per cubic centimeter of blood serum.
4. Patient received 1000 international units of vitamin D per day.
5. In the specimen obtained, + represents new bone present; 0, new bone absent; ? indicates that new bone may have been present on the medial side of the callus, but was not found in the lateral or excised part of the callus; – indicates that no observation was made.
6. Osteoid: Amount of osteoid in the callus is estimated from + to ++++. +: Fine osteoid borders are present on heavily calcified bone. ++ to +++: Wide osteoid borders are present on uniformly calcified trabeculae. ++++: Areas of completely uncalcified osteoid are present in callus in which the new bone in general is poorly calcified.
7. Calcium deposits: In roentgenograms, calcified callus is new bone, with the density of secondary spongiosa, which is radiopaque. 0–+: Calcification is visible on the medial side of the callus on the upper fragment, but not on the lateral side from which the specimen was obtained.
8. Manipulation and insertion of a Steinmann pin was done on the day of the fracture.
9. Reduction was complete or nearly complete.

Howship, Gümbel, Pochhammer, Bier [7], Keith, Bancroft, Koch, Murray [72, 73, 74], Phemister [83, 84], Block, and Bennett and Bauer. Ferro-Luzzi investigated the origin of osteogenic tissue in human material obtained at operation on twenty-one patients with various fractures, and Orth described in great detail healing, after fifteen and thirty-five days, of intertrochanteric and subtrochanteric fractures of the femur as found at autopsy. Von Schlotheim, Martin, Wieder, and many others have transferred personal and inherited observations on experimental fractures to the interpretation of roentgenographic records of clinical fractures. Most of the human material available for study in the investigations assembled above has been fragmentary and unsuitable for detailed study [78], and leaves much to be desired as an aid in understanding the particular problems of healing in clinical fractures.

II. MATERIALS AND METHODS

The specimens of callus studied by the authors were obtained from all types of fractures through the shaft and metaphyses of the various long bones of the body, as shown in Table I.

Except for two cases of fractures of the middle third of the shaft of the femur, which were well aligned, and upon which biopsy operations were done, all of the material was obtained incidental to treatment leading to reduction of the fracture, correction of malposition, or internal fixation. The biopsy operations are considered sources of the control cases for evaluating the effect of malposition of the main fragments on the organization of the growing callus. In thirty-six cases, the entire lateral half of the callus was obtained, including the contents of the marrow cavity at the fracture line. In six cases, only a quadrant of the subperiosteal or external callus was available. In four cases, the entire mass of the extracortical tissue at the fracture line was excised.

The tissues were prepared undecalcified by histological methods described and evaluated in the course of detailed studies of embryogenesis [12], growth [63], and repair [100, 101, 102] of bone. The extreme sensitivity of the silver-nitrate, hematoxylin, and eosin staining reaction which has been employed routinely, is shown in the histochemical experiments of Bloom and Bloom and in the observations of Urist and McLean [100] on the corresponding optical properties of serial stained and unstained, undecalcified sections of rachitic and normal bone in various stages of calcification. The callus of healing fractures of the large long bones of the human may also be sectioned undecalcified with facility until about the fiftieth day of healing. Between fifty and ninety days of healing, when the bone of the callus forms with increasing density, the method is practical only on small blocks of tissue.

Experienced bone microscopists may question the justification of the use of the histological techniques on undecalcified bone on the claim that osteoid tissue may be distinguished from calcified bone by the smooth outlines, homogenous matrix, and pale staining of the trabeculae with

eosin. While this distinction is possible when the bone is calcified to the maximum as compared with no calcification at all, it is unreliable and often totally useless for bone tissue in the various intermediate stages of the calcification of the trabeculae.

Levels of serum calcium were measured by the Clark and Collip modification of the Kramer and Tisdall method, of serum phosphorus by the technique of Fiske and Subbarrow, and of serum alkaline phosphatase activity by the procedure of Bodansky.

III. THE GENERAL PATTERN OF FRACTURE HEALING

Eliminating differences in detail which are described in the following sections, there is complete similarity in the general pattern of bone repair in man and animals. The gross structure of this pattern includes the three types of tissue—granulation tissue, fibrocartilage, and bone—which are seen on examination of the fracture site at operations. *Procallus,* is the term applied to the organizing hematoma and highly vascular granulation tissue which develops in the first weeks of healing. Although the same in appearance as in wounds elsewhere in the body, in the bone the undifferentiated connective-tissue cells exhibit the power to differentiate into *fibrocartilaginous callus,*—a translucent mass of dense fibrous connective tissue, fibrocartilage, and cartilage which is seen from the second or third week of healing until the time of union. The *bony callus* originates in some fractures as early as the first week, through the proliferation of spindle-shaped cells in the inner layer of the periosteum and the endosteum of the fracture ends, which then become recognizable as osteoblasts and deposit new bone on the medullary and periosteal surfaces of the injured cortex. About the third to fourth week of healing, the new bone grows from the endosteal and subperiosteal bony callus into the fracture gap by replacing the fibrocartilaginous callus in the wake of invasion by blood vessels, primordial marrow, spindle-shaped connective-tissue cells, and osteoblasts.

In fractures of the large long bones in man, the time sequence of these various processes is obscured by the overlap in the appearance of new structural changes. The hematoma is so large that organization of its core is incomplete at the time its periphery of granulation tissue is developing into fibrocartilaginous callus, and collars of new bone of considerable volume are already constructed around the main fragments. In a healing fracture of the femur at any time between twenty and forty days of healing, every phase of bone repair is visible in a single case. Coordinated and organized like the morphogenesis of an embryo, differentiation and growth of new connective tissue are directed by diverse means to a common end,—that is, the development of bone across the fracture ends.

IV. THE PROCALLUS

The outstanding feature of the procallus in clinical fractures is its content of fragmented injured tissue,—fascia, muscle, bone, marrow,

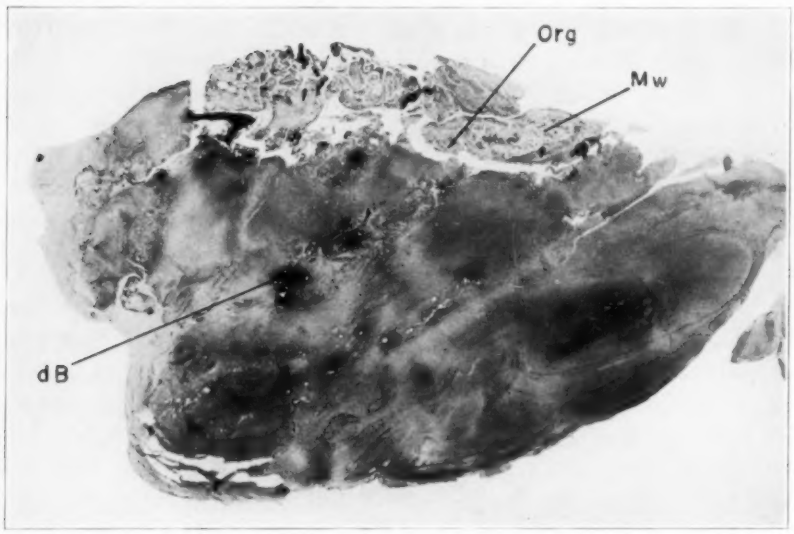

FIG. 1

Case 110. Photomicrograph (×5) of the hemorrhagic mass excised from the space between the ends of the fracture of the shaft of the humerus after four days, showing displaced patch of marrow (*Mw*), fragment of dead bone (*dB*), and organizing fibrin containing fragments of macerated muscle (*Org*). (All sections illustrated were cut undecalcified, impregnated with silver nitrate, and counterstained with hematoxylin and eosin, unless otherwise stated.)

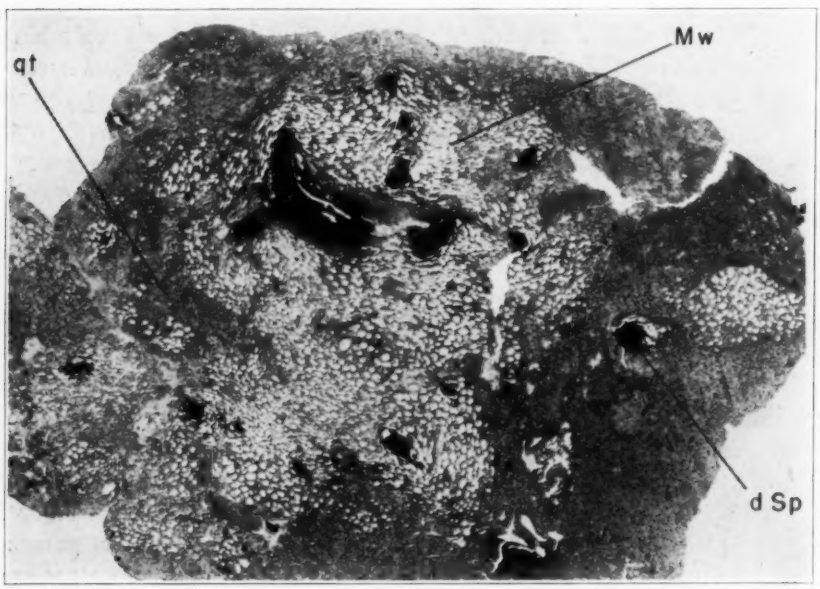

FIG. 2

Case 149. Photomicrograph (×14) showing the reaction to injury of the myeloid tissue in a specimen obtained by curettement of the medulla of the proximal fragment after eighteen days of healing. Granulation tissue (*gt*) replaces the marrow reticulum (*Mw*) between the patches of persisting fat cells. *d Sp:* dead spongiosa.

articular cartilage, and capsular ligament (Figs. 1, 3, 5, and 14). The fragments are of microscopic and gross proportions, and may be isolated or attached at one end as a flap or fold inserted into the fracture space. The acute inflammation of the first week of healing occurs alike in the substance of the fibrin of the blood clot, in necrotic marrow, in muscle about the fracture line, and in the interstices of displaced tissues. Further changes in the structure of injured tissues are directed toward absorption and replacement by fibrous connective tissue or bone, the details of the process varying considerably with each type of tissue.

Blood Clot

Extravasated blood is almost entirely coagulated, but is partly also in serosanguinous fluid and inflammatory exudate. In the first twenty-four hours, organization begins superficially outside the fracture site from the vascular structure of the injured periosteum, muscle, and marrow (Figs. 1 and 3), and leads to infiltration of the meshes of the fibrin by polymorphonuclear leukocytes, lymphocytes, and marcrophages. Differentiation of granulation tissue begins in this background, as described by Marchand, which differs from the picture of septic inflam-

FIG. 3

Case 156. Photomicrograph (×200) showing acute inflammation in the endomysial connective tissue of a fragment of muscle displaced into the fracture gap, with an attached particle of dead bone, after five days of healing of a fracture of the ulna.

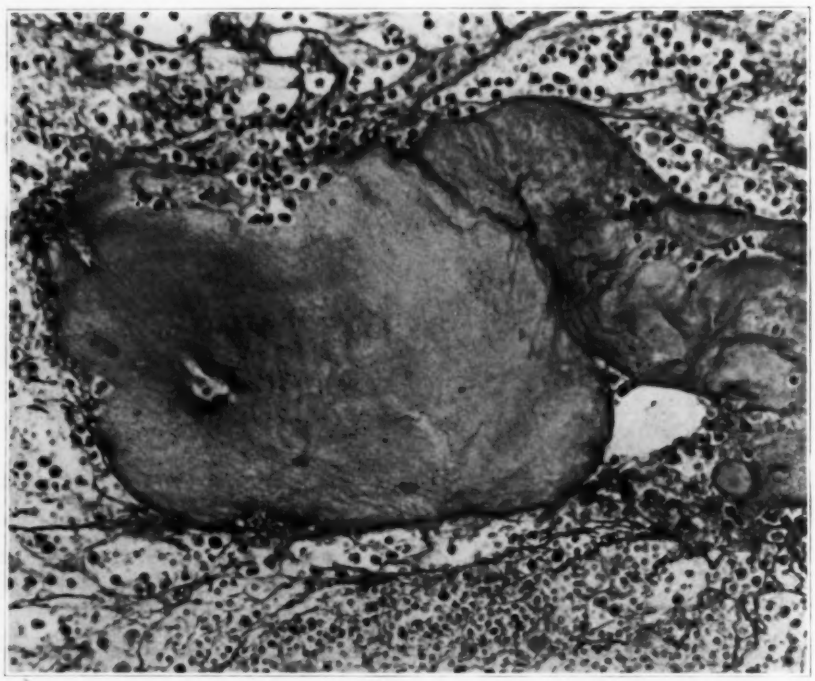

FIG. 4

Case 156. Photomicrograph (×250) of a fragment of articular cartilage in organizing blood clot from the same case as shown in Fig. 3. Note polymorphonuclear leukocytes and lymphocytes in the inflammatory tissue in the fibrinous network in the background.

mation only in that the inciting principle or irritant does not reproduce itself [46].

In the large long bones in man, the extreme size of the hemorrhagic mass and the large volume of foreign tissue contained in it require considerable time for organization and absorption. As long as thirty to sixty days may elapse before the inner parts are involved in the inflammatory reaction, in which time fibrin and necrotic fragments of fascia and muscle may become hyalinized. This tissue, which is of nondescript character, may be observed to calcify in rare instances, but in all of the authors' cases there was no calcium deposited in the procallus or granulation tissue prior to new-bone formation.

Injured Muscle

The muscle incorporated in the callus rapidly undergoes necrosis or typical fibrous degeneration, depending upon whether it is isolated tissue (Fig. 3) or whether it is a flap with blood supply engaged between the fragments (Fig. 15). Within five to ten days, the isolated tissue shows endomysial capillary hemorrhages, acute inflammation, and necrosis of the myocytes which lead to autolysis and dissolution of the muscle fibers. Interposed muscle flaps show relatively little hemorrhage and inflam-

matory reaction, but some cellular infiltration gradually appears and often gives rise to subacute and chronic inflammatory tissue which persists in the muscle until it is absorbed through fibrous degeneration and ossification. In fibrous degeneration, the muscle fibers gradually shrink or become attenuated, the nuclei of the muscle cells become pyknotic and fragmented, the myoplasmic striations dissolve, and the cells hyalinize or disintegrate. The muscle tissue is replaced by scar.

Bone Marrow

The injured bone marrow in the medulla at the fracture line (Fig. 2) and fragments of myeloid tissue carried into the fracture hematoma (Fig. 14) both undergo fatty degeneration. The reticulum is first filled with the extravasated blood of numerous capillary hemorrhages. Necrosis, autolysis, and degeneration of the myeloid tissue follow within a few days. Inflammation and organization of the interstitial patches of fibrin usually follow, but may be delayed in the case of isolated fragments. The fat cells remain as long as fifty days, or more, of healing in the fibrous connective tissue which develops in the persisting reticulum.

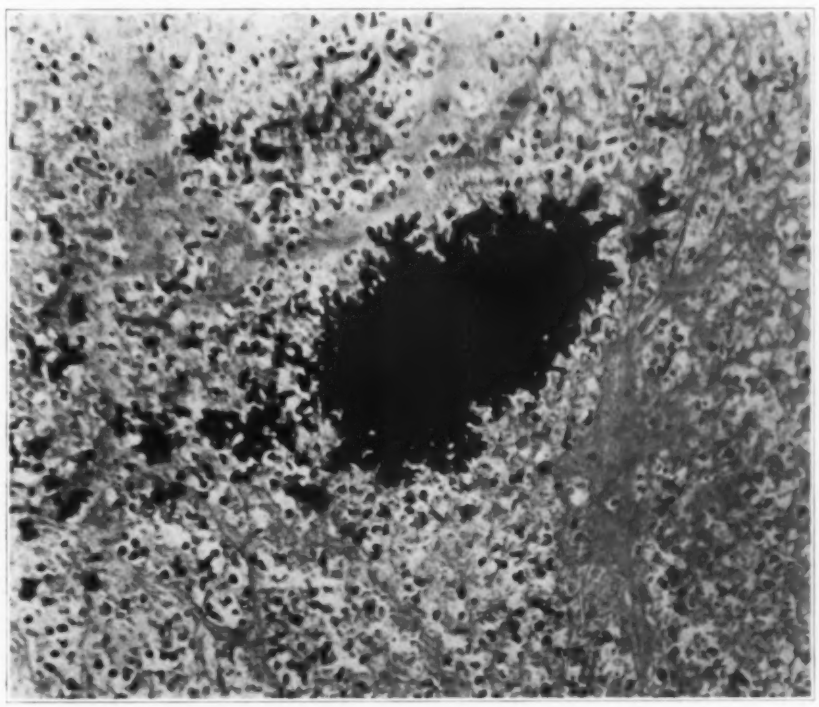

FIG. 5

Case 156. Photomicrograph (×275) of another section from the same case as shown in Figs. 3 and 4, showing a fragment of dead bone embedded in organizing fibrin. Note the crystalline pattern of the surface suggesting reprecipitation of dissolved bone salt. Particles of bone of this size are broken off from the spongiosa of the fracture ends in the course of manipulations in treatment.

Articular Cartilage, Capsular Ligament, and Fascia

These tissues show no particular reaction to injury, and are incorporated in scar or new bone in which they become absorbed slowly (Fig. 2). Necrosis of the various cells is often difficult to demonstrate.

Bone

Necrotic injured bone is found in the main fragments at the fracture line, and as isolated pieces of bone which similarly undergo necrosis and absorption. In *all* of the cases reported here, there are pieces of bone enclosed in the hemorrhagic mass between the fracture ends, ranging in size from segments of the whole thickness of the cortex (Fig. 25) as in "clinically" comminuted fractures, to microscopic and fine particles not demonstrable by roentgenograms. The smaller particles, as recognized by the histological architecture, are derived either from spongiosa or shaft. The few particles of spongiosa found in fractures of the shaft are dislodged from the inner surface of the cortex, and these, as also the trabecular particles of bone detached from the cancellous bone of fractures

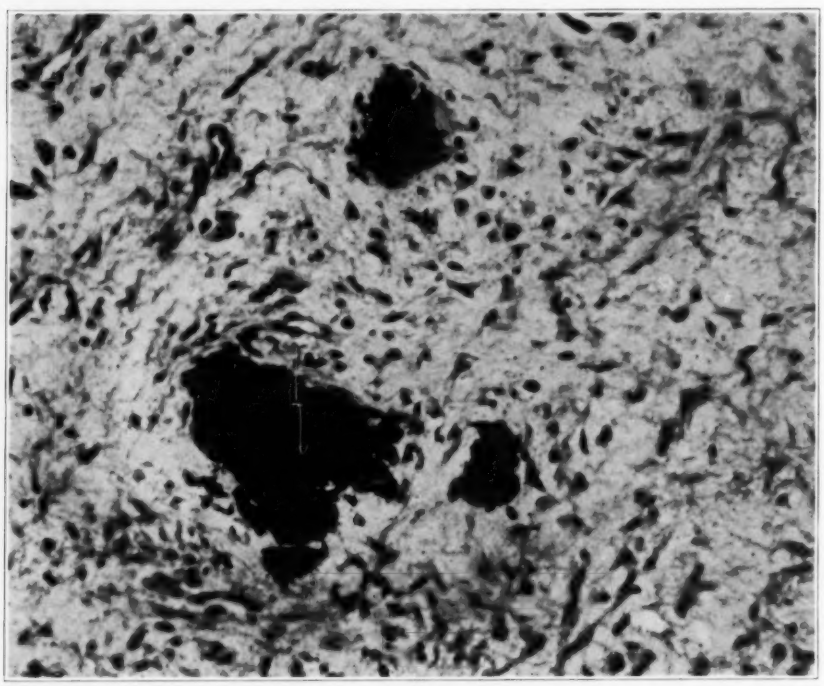

FIG. 6

Case 184. Photomicrograph (×275) showing a fragment of bone in the process of absorption after the organizing hematoma has been replaced by proliferating granulation tissue. Note the *surface erosion* or *granular crumbling* of the dead bone, in which the bone matrix and the bone salt disappear simultaneously as small particles in the interstices of the connective-tissue cells. Under oil-emersion lenses, finer particles of silver-staining material are occasionally found to be phagocytosed by macrophages.

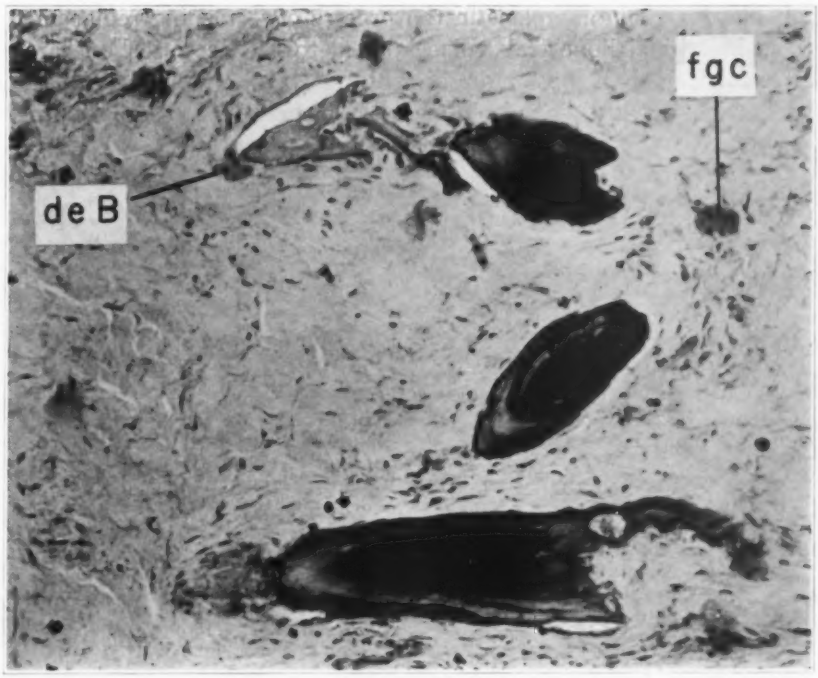

FIG. 7

Case 170. Photomicrograph (×200) of the dense fibrous connective tissue developed from granulation tissue after fifty-five days of healing, and containing several fragments of necrotic bone, one of which (*deB*) is completely decalcified, while the others still retain part of the bone salt, and show the margin of bone matrix from which the salt has been lost. *fgc:* foreign-body giant cell.

of the metaphysis, carry an envelope of osteogenic tissue and marrow (Fig. 14). The displaced particles of cortical bone are bare, and contain only the little perivascular connective tissue contained in the haversian canals.

The detail of the absorption of injured bone is modified by the relationship of the dead bone to viable tissue with blood supply, and by whether it contains adnexa of surviving connective tissue with osteogenic potency. The dead bone at the fracture line and the displaced bone particles located outside the main hemorrhagic mass may show circumscribed proliferation of osteogenic connective tissue, with deposition of new bone on the old trabecular structure. As is the fate of autoplastic transplants to soft tissue [25, 82, 31], the acellular old bone is absorbed at the same time that the new bone is laid down upon its surfaces. This process, often termed "creeping replacement" [4, 6], shows no detail at the line of apposition of the new bone and the old bone, and erosion appears to occur between the trabeculae at points of contact of the blood vessels and osteogenic connective tissue. No osteoclasts are seen on the dead bone. In undecalcified sections, it is found that the old bone retains its calcium throughout the process of absorption, and does not show preliminary decalcification. Local transfer of bone salt from old to new bone

probably does not take place in the process of "creeping replacement", as the individual bone trabeculae applied to the necrotic bone are not better calcified than those more distant.

Particles of dead bone isolated in the hemorrhagic mass between the

FIG. 8

Case 188. Photomicrograph (×5) of a strip of new bone which was cut from the outer surface of the cortex at the site of a fracture after twenty-three days of healing, in a fifteen-year-old boy. This is the first deposit of bony callus which forms subperiosteally for some distance from the fracture line. The area enclosed in the rectangle is shown in Fig. 9.

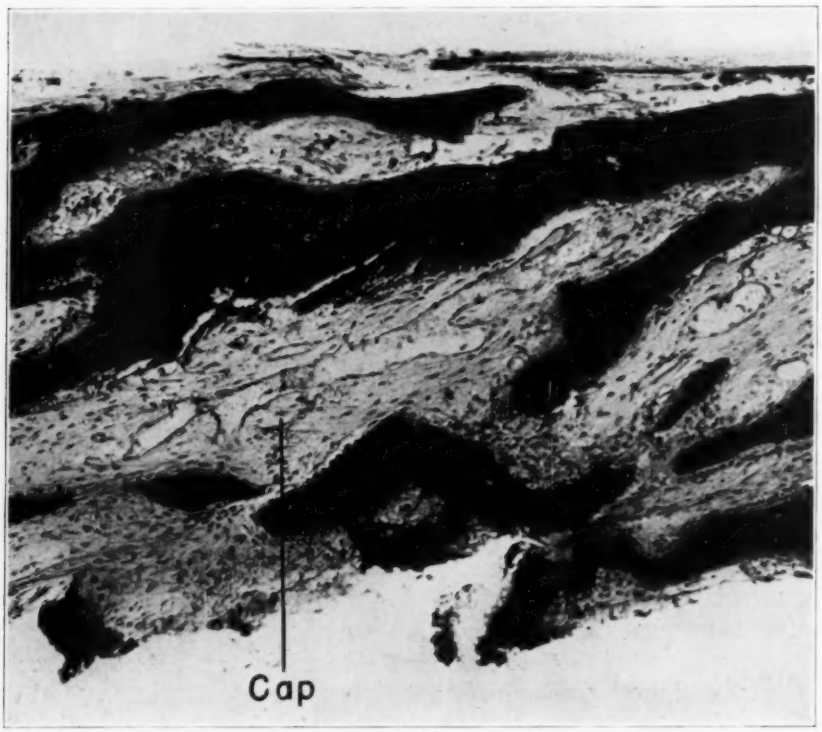

FIG. 9

Case 188. Photomicrograph (×180) of area indicated by the rectangle in Fig. 8. Between the individual new-bone trabeculae are blood vessels (*Cap*) derived from the periosteal blood supply, which divide into the smaller vessels and capillaries passing toward the bone tissue to the layer of osteoblasts. It is through the capillaries and intercellular fluid that calcium and phosphorus, the building stones of the bone salt, are brought to the bone matrix in solution. Osteoid borders are seen on some but not all of the trabeculae.

fracture ends are absorbed in the course of organization of the fibrin simply by solution or surface erosion. During the stage of acute inflammation, the fibrinous network around the bone particles is evidently saturated with calcium salt, as seen by the frondose surface pattern formed through recrystalization in silver staining of the bone salt (Fig. 5). Surface recrystalization of the calcium salt is not seen in bone particles in granulation tissue. The picture changes to that of *granular crumbling* (Fig. 6), in which particulate bone is dislodged from the surfaces, the bone salt and the bone matrix passing into solution simultaneously. After twenty-five to fifty days of healing in the dense fibrous connective tissue developed from the granulation tissue of the procallus, the remaining particles of dead bone often show decalcification in advance of the disintegration of the matrix (Fig. 7). This is the only condition in which the authors have seen calcium salt withdrawn from bone, without concurrent disintegration or solution of the osseous organic structure.

Necrotic bone remaining in the fibrous connective tissue between the fracture ends, when osteogenesis advances across the fracture gap, is also finally absorbed by creeping replacement. Absorption of large fragments of the full thickness of the cortex may require many months; they are often seen long after consolidation of the fracture is complete.

Summary

The structure of the procallus is unique in clinical fractures, especially those subjected to multiple attempts at reduction, in that it is complicated by the inclusion of injured soft parts and fragments of dead bone, which

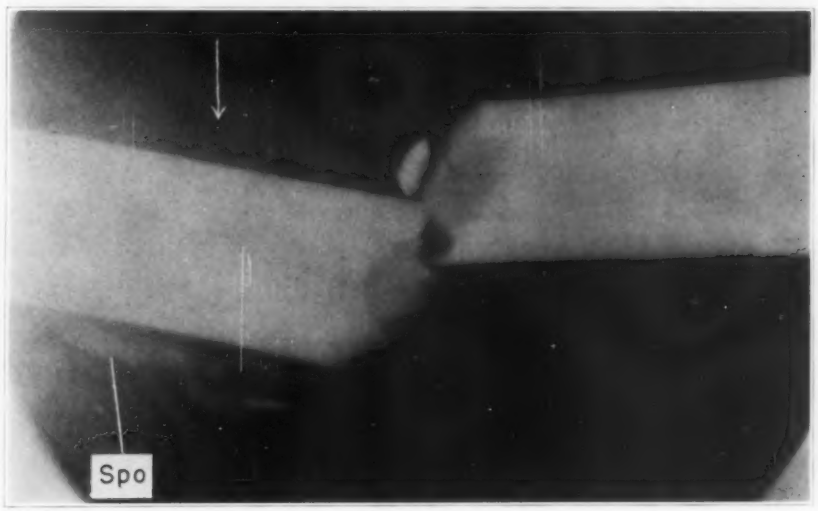

FIG. 10

Case 198. Roentgenogram in anteroposterior view of the callus of a fracture of the middle third of the femur after eighteen days. The bony callus (*Spo*) first makes its appearance in the area of calcification seen on the medial side of the upper fragment. A block of tissue was excised from the area indicated by the arrow (Fig. 11), at open-reduction operation in which the fracture site was exposed through a lateral incision.

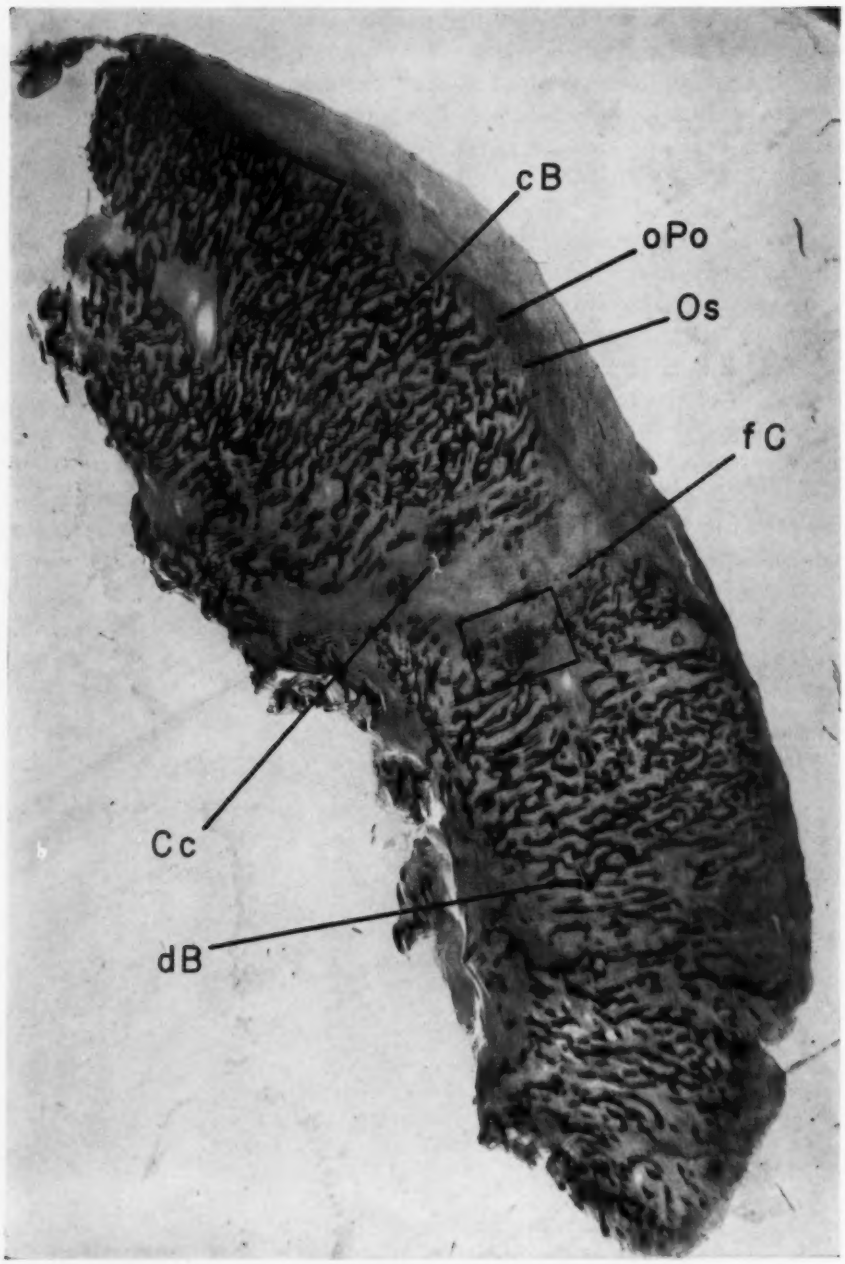

FIG. 11

Case 198. Kodachrome photomicrograph (×9) of a section of a specimen of callus excised from the area at a distance from the fracture gap indicated by the arrow in Fig. 10. This shows mainly bone, but also includes a band of fibrocartilaginous callus (*fC*); spongiosa (*cB*), newly deposited and incompletely calcified; osteogenic layer of periosteum (*oPo*); osteoid (*Os*), completely uncalcified; calcified hyaline cartilage (*Cc*); and denser bone (*dB*), more heavily calcified and of the structure of secondary spongiosa. The area outlined in the upper rectangle is shown in Fig. 13. The area indicated by the lower rectangle is shown in Fig. 12. The cartilage and bone matrix containing bone salt are stained dark brown or black.

may be regarded as characteristic of accidental complete fractures. The absorption of injured structures begins with organization of the hemorrhagic substance, is accomplished by means of various cellular and chemical reactions which are characteristic of the different types of dead tissue, and is conditioned by changes in the composition of the callus in the course of healing.

V. THE CALLUS

The callus, as already stated, consists of a fibrocartilaginous part and a bony part which develop more or less simultaneously. As early as the first week of healing the fibrocartilaginous callus begins its formation by the differentiation of the granulation tissue or primitive connective tissue cells into: (a) islands of hyaline cartilage which grow and form bizarre-shaped nodules, (b) patches and bands of fibrocartilage which pass between the masses of cartilage, and (c) dense fibrous connective tissue which encapsulates the cartilage or forms septa conveying larger blood vessels through the callus. If angulation is present without displacement, the volume of the callus is greater on the concave side than on the convex side.[51, 72, 103]

Whether the fragments are well aligned and the callus is small, or whether the fragments are inadequately reduced and the callus is volumi-

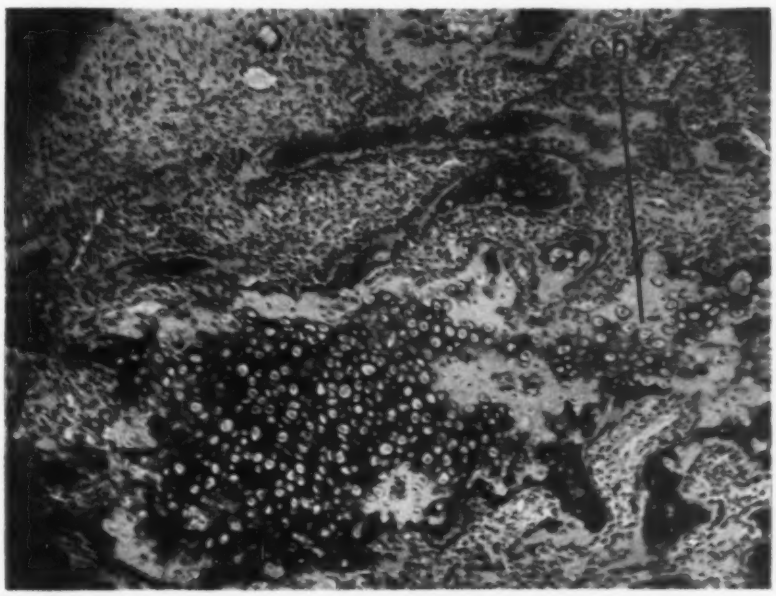

FIG. 12

Case 198. Kodachrome photomicrograph (×70) of the area outlined by the lower rectangle in Fig. 11, showing a patch of hyaline cartilage in the fibrocartilaginous callus which is calcified preliminary to penetration of osteogenic tissue and its replacement by bone. Encapsulating the cartilage, however, is chondro-osteoid tissue (*chO*), which is the same as that seen in endochondral ossification of the rachitic metaphysis, and reflects the lag in provisional calcification of cartilage matrix.

nous, hyaline cartilage and fibrocartilage develop into an irregularly shaped disc that grows until it covers the fracture ends and extends out into the subperiosteal or external callus all around the fracture line. In addition to the main fibrocartilaginous disc, the outlying bony portions of the external callus show isolated groups of cartilage cells, either in bone trabeculae or forming in small islands in the osteogenic tissues. Osteogenesis and chondrogenesis thus may progress simultaneously, and the structural products are mixed into an irregular lattice. The immature cartilage so embedded in the bone tissue outside the main cartilaginous mass is calcified massively and indistinguishably from the surrounding osseous tissue when stained to show the bone salt (Figs. 11 and 15).

On retraction of the inflamed periosteum and muscle, during operation on fractures at about the end of the first week, the exposed cortex presents a thin, freely bleeding, layer of granular spongy bone extending five to ten centimeters from the fracture line (Fig. 8). This layer, readily cut from the cortex by means of a sharp osteotome, histologically consists of parallel obliquely aligned trabeculae with loops of delicate blood vessels suspended between them (Fig. 9). At approximately the same time, the endosteum lining the cancellous bone on the inner surface of the cortex proliferates and gives rise directly to new-bone tissue branching into the marrow cavity for some distance from the cortical ends (Fig. 27). The osteoblasts or osteogenic cells which lay down the new bone arise from proliferation of *spindle-shaped cells* of the inner layer of the periosteum and periosseous marrow, currently described [11, 13] as "resting osteoblasts". With continued intramembranous bone formation, four wedge-shaped collars of bone grow on the surfaces of the cortex and, together with the interposed growing fibrocartilaginous disc, form a spindle of callus which fastens the fragments together as previously illustrated schematically [100].

The new bone laid down in the first ten days of healing is calcified shortly after construction of the bone tissue, as is evident by the narrow osteoid borders on most of the trabeculae (Fig. 9). However, some of the trabeculae do not show osteoid borders. As the volume of the callus increases, or as the rate of the new-bone formation reaches its height, there is a further lag in calcification of the new bone. In the average adult, at about twenty to fifty days of healing, almost all of the new-bone tissue is ensheathed in wide borders of osteoid (Fig. 13), a small part is completely uncalcified, and a smaller part is, in contrast, totally calcified. As a rule, the older bone tissue applied to the shaft is not only denser, but is also better calcified, while most of the poorly calcified bone is the newly deposited tissue located subperiosteally (Fig. 11).

The intramembranous deposits of bone grow in volume and extend toward the fracture line until about the third week of healing, when contact is gained with the fibrocartilaginous callus. The various tissues in the fracture gap at this time are penetrated by blood vessels, primitive marrow, and spindle-shaped cells which show various shades of basophilia and an increasing prominence of the Golgi net of the nuclei, the closer

they are to the polygon-shaped, deeply basophilic osteoblasts and bone tissue. These elements, including the "spindle-shaped osteoblasts" [13], comprise the so-called *osteogenic front* (Fig. 14) which is an irregular

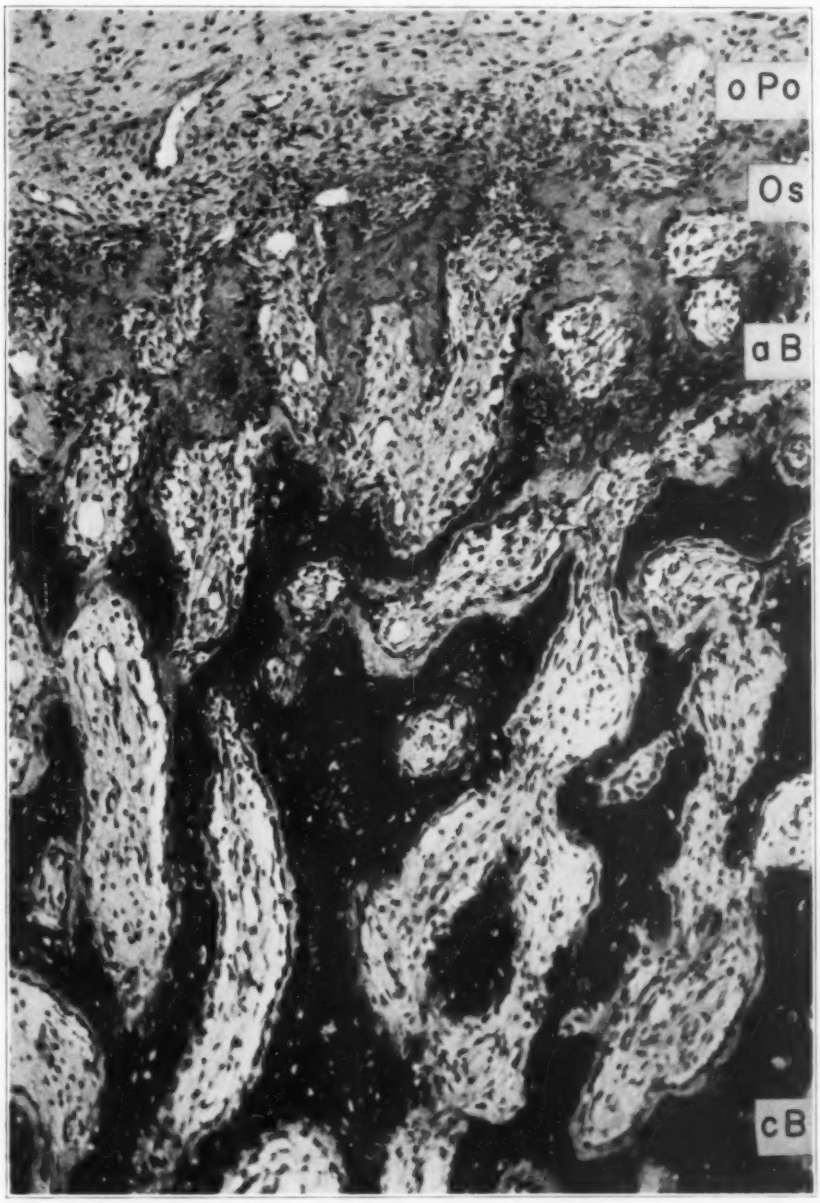

FIG. 13

Case 198. Photomicrograph (×120) of the area shown in the upper rectangle in Fig. 11, showing that bone salt is absent in the most recently deposited bone in the zone (*Os*) between the osteogenic layer of the periosteum (*oPo*) and the newly calcified trabeculae in the zone *aB*. In the zone *cB* the trabeculae have increased in volume; the mineral deficit is still present, as is seen by the wide osteoid borders.

zone through which the bone advances into the various tissues of fibrocartilaginous callus. The growth of bone appears to proceed into the dense fibrous connective tissue of the callus by the development of the undifferentiated connective-tissue cells of the terrain into osteoblasts at the osteogenic front, but it is not possible to distinguish between the "fibroblasts" which are to be absorbed or remain unchanged and the cells which are to contribute to osteogenesis. This process of invasion by bone differs from invasion in the sense of a malignancy in that there is no random destruction of tissue, but actually systematic infiltration, resorption, and differentiation of the existing cellular elements.

Corresponding to the irregularity in the structure of the nodules of cartilage and the bands of fibrocartilage and fibrous connective tissue, the cartilage cells are either invaded and calcified, or penetrated incompletely and included massively calcified in the bone tissue, or penetrated incompletely and not at all calcified. The latter picture, seen only in the early stages of callus formation, represents the rachitic type of cartilage removal, and reflects the absence of provisional calcification of the cartilage matrix (Fig. 12). It results in the formation of *chondro-osteoid*,—the mixture of osteoid and cartilage tissue, characteristically found in the rachitic metaphysis as a result of disorderly endochondral ossification.

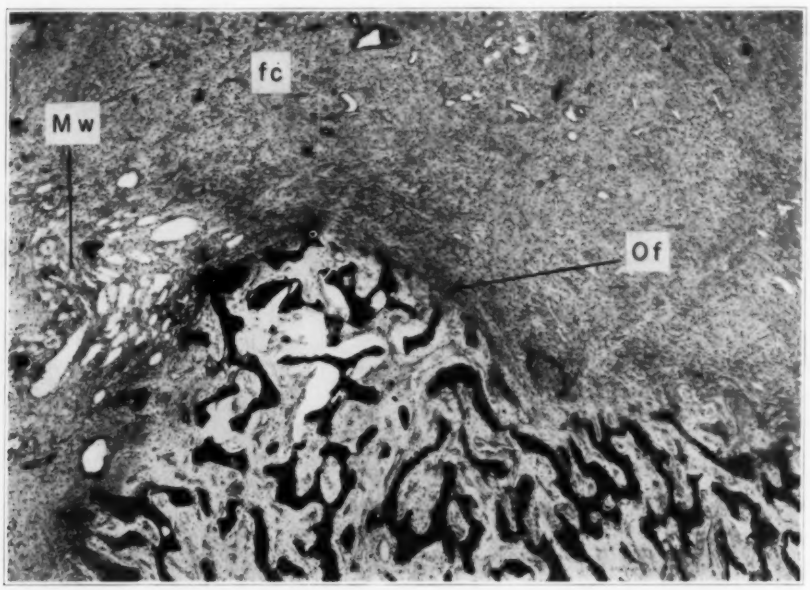

FIG. 14

Case 177. Photomicrograph (×20) of a section showing the junction of the fibrous connective tissue (*fc*) of the fibrocartilaginous callus, and the new bone growing in from the fracture ends. The growth of bone advances along the osteogenic front (*Of*), which contains osteoid tissue, at some but not all points, and replaces the connective tissue through the proliferation of osteoblasts and differentiation of some of the spindle-shaped cells into osteoblasts, leaving others unchanged or to be resorbed. *Mw:* patch of necrotic marrow containing several particles of dead spongiosa.

In the intermediate and later stages of healing, the chondro-osteoid disappears with improvement of calcification, and the picture assumes more regularity. Fibrocartilage is calcified superficially, and the hyaline cartilage is impregnated more deeply, when contact is made with the osteogenic front (Fig. 24). Ossification proceeds thus with resorption of a large part of the cartilage, and with deposition of new bone on the surfaces of calcified matrix of the intervening parts. In the later stages of healing, and especially prominent at the time of the uniting of the fracture (Fig. 27), remnants of the fibrocartilaginous callus persist embedded in dense formations of bone, and are fully calcified. Within this apparently haphazard pattern, resorption of fibrocartilage and cartilage continue, but a large part of the cartilage appears to lose its basophilic staining and gradually to disappear in the osseous tissue as though through transformation of the chondrocytes into osteocytes. This transformation, regarded by some authors as metaplasia [105, 36, 37], is a prominent feature of the ossification of the callus in man.

Relatively speaking, all of the bone of the callus is new bone, but the older trabeculae in the inner parts of the callus, when seen after forty or fifty days of healing, are lined by spindle-shaped cells rather than by the polygon-shaped, rapidly proliferating osteoblasts seen around the newly deposited bone in the outer callus. The spindle-shaped cells here are comparable to the so-called "resting osteoblasts" in the inner periosteum and the lining of the marrow cavity. As the bony callus increases and the fibrocartilaginous callus decreases in volume, the trabeculae closest to the fracture gap gradually increase in thickness by means of deposition of concentric lamellae of bone, until the familiar whorled arrangements of the haversian systems are developed (Fig. 26).

The callus is remodeled and molded continuously by means of resorption of the new-bone tissue along certain lines and reconstruction of the trabeculae along other lines. Through the formation of osteoclasts and fibrous connective-tissue cells, regarded as dedifferentiation by current writers [64, 13], the osteocytes and the osteoblasts disappear into the osteogenic tissues and fibrous marrow between the trabeculae, at the same time that the bone matrix disintegrates and the bone salt is mobilized in the tissue fluids in solution. These cellular changes are seen only in the resorption of living bone tissue, and have been observed in experimental hyperparathyroidism in rats [64], in pigeons during the egg-laying cycle [13], and in the bones of various animals in answer to the demands of ordinary growth upon the readily available stores of calcium and phosphorus in the cancellous bone tissue [63]. Previous experiments have shown that through osteoclasis and dedifferentiation of bone cells—thus particularly in the resorption of living bone as distinguished from necrotic bone—the bone salt is mobilized in a form, possibly primary calcium phosphate ($CaHPO_4$) [65], which is immediately available for redeposition in closely adjacent new-bone matrix. Osteoclasts and spindle-shaped osteoblasts may be regarded as the by-products of the disintegrated bone tissue. The

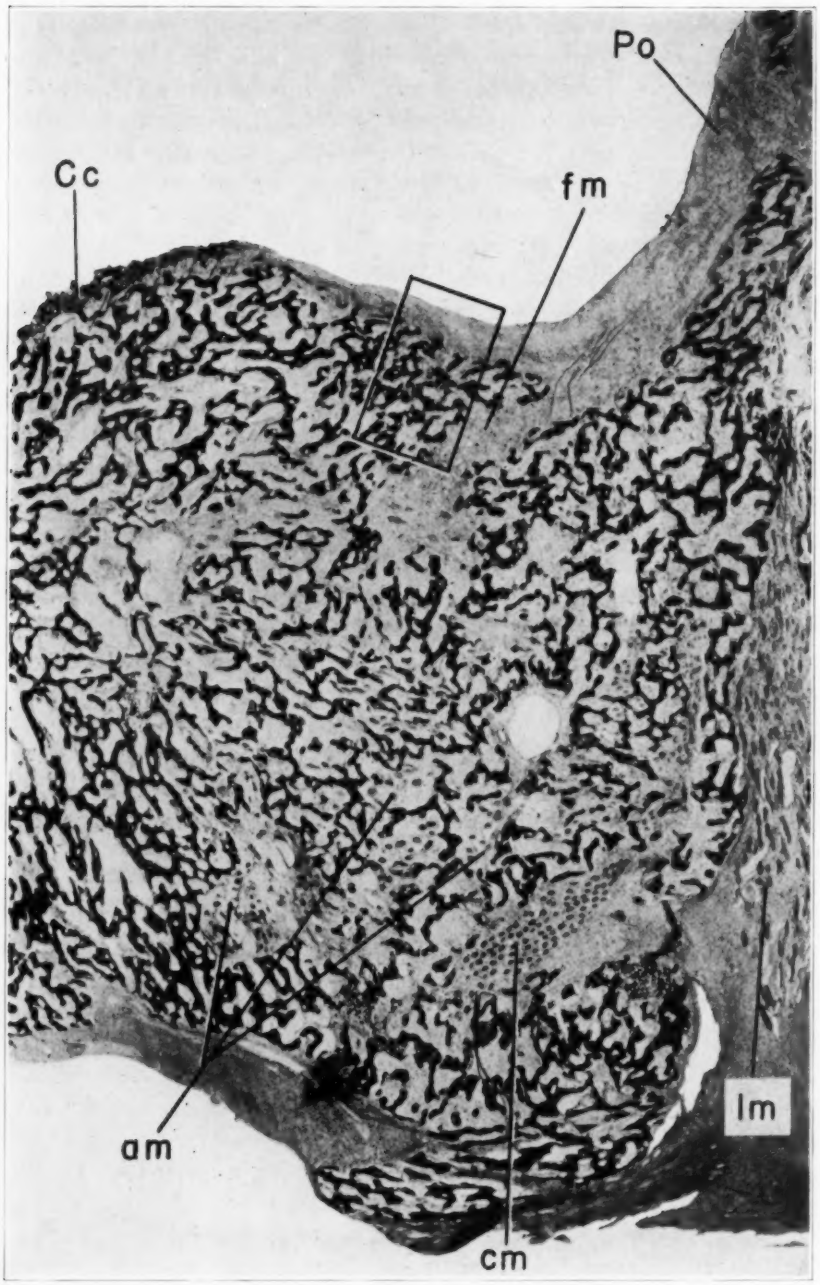

FIG. 15

Case 147. Photomicrograph (×15) of section through the external bony callus of a fracture of the femur after nineteen days of healing, showing the muscle tissue incorporated in the callus, in various stages of fibrous degeneration. Atrophied muscle is seen in oblique section (*lm*), and in cross section (*cm*). The fragment of muscle (*am*), shows fewer muscle fibers and more connective tissue, and the fragment (*fm*), is almost entirely dense fibrous connective tissue, and contains only an occasional hyalinized muscle cell. Note the muscle cells (*am*) here and there between the trabeculae; periosteum (*Po*), and calcified cartilage (*Cc*). The area indicated by the rectangle is shown in Fig. 16.

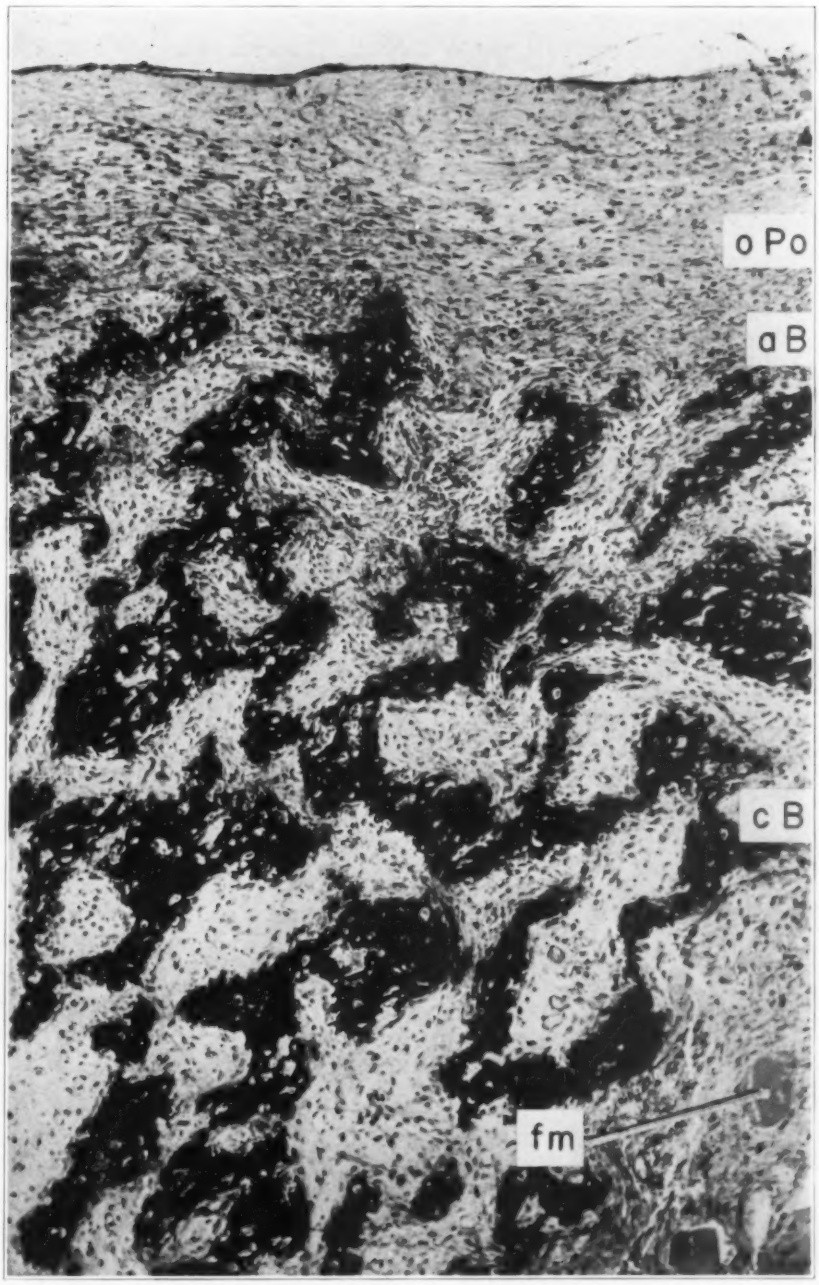

FIG. 16

Case 147. Photomicrograph (×120) of a section through the area indicated by the rectangle in Fig. 15 showing that, in some parts of the human callus, the bone is calcified as rapidly as it is laid down. There is relatively little osteoid as compared to the picture in Fig. 13. *oPo* is periosteum; *aB*, osteogenic layer of the periosteum; *cB*, bone trabeculae with complete calcification; *fm*, muscle cells in the edge of the area *fm* shown in Fig. 15.

conditions which instigate bone resorption in one place and bone construction in nearby places are unknown. Delicate changes in capillary permeability associated with changes in the concentration of calcium and phosphorus in serum and lymph, alterations in the pressure of the intercellular fluids accompanying proliferation of new cells and resorption of others, and other local variables may be offered as hypothetical considerations for interpreting the histological picture of bone resorption.

VI. THE CHANGES IN THE SHAFT ACCOMPANYING BONE REGENERATION

The segment of the shaft which becomes enclosed in callus consists of two distinct parts [23, 90],—the *necrotic bone along the line of injury* of the main fragments and the *living cortical tissue*. Specimens of the fracture ends resected for examination (nine cases) show that the necrosis of the cortex extends approximately one centimeter, varying more or less with the irregularity of the fracture line and the relationships of the blood supply to the area. Fractures through the metaphysis generally show only

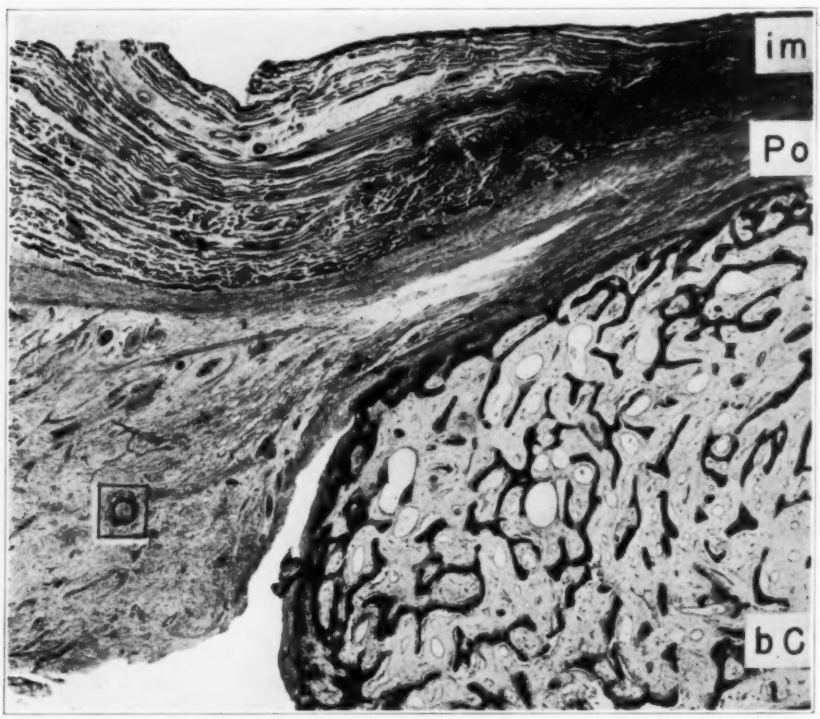

FIG. 17

Case 113. Photomicrograph (×12) of a section through the surface of the callus after eighty-eight days in a fracture, showing the prolonged inflammatory reaction in the soft tissue outside the periosteum at the site of the fracture. Note the perivascular round-cell infiltration and focal collections of lymphoid tissue in the outer layer, and scar tissue of the periosteum (*Po*) and the perimysial connective tissue. Muscle containing chronic inflammatory tissue is seen at *im* and bony callus at *bC*. The area indicated in the rectangle is shown in Fig. 18. Hematoxylin and eosin staining were used.

a few millimeters of necrosis.

It has been shown in fractures in animals[23, 100, 102], that the uninjured part of the shaft enclosed in callus undergoes progressive osteoclastic resorption of endosteal and periosteal surfaces of the shaft in the course of healing. In young, rapidly growing animals, this process is so extensive that rarefaction of the shaft continues until the compact bone is deeply perforated with wide tortuous channels filled with osteogenic tissue, osteoclasts, and blood vessels coursing between the periosteum and the medulla. The cortex becomes almost as porous as spongy bone. The outlying subperiosteal bone increases in density as the shaft is rarefied, and in this way the shaft enclosed in callus is entirely reconstructed before the fracture is consolidated and the callus is entirely resorbed.

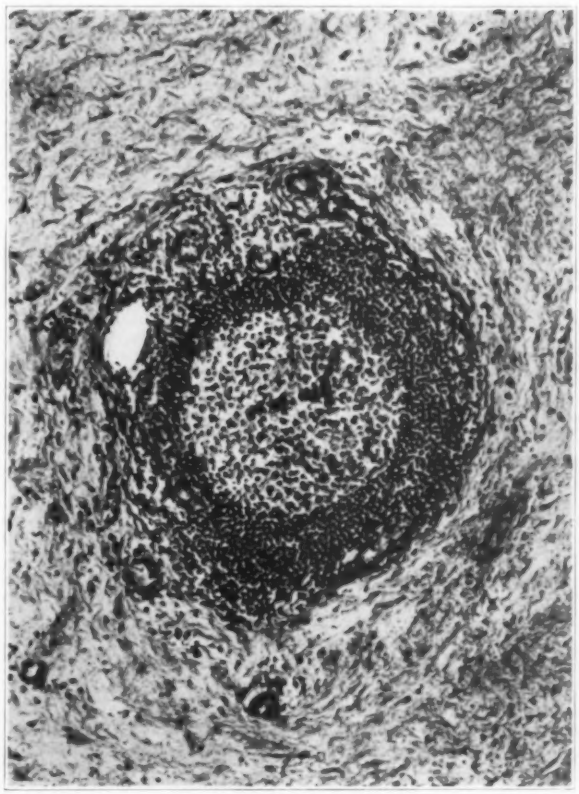

FIG. 18

Case 113. Photomicrograph (×150) of the area outlined by the rectangle in Fig. 17, showing one of the typical lymphoid nodules occasionally found in the chronic inflammatory tissue outside the periosteum.

The rarefaction of the callus-enclosed shaft has been demonstrated amply in gross specimens of fractures in adult man by Curling, Paget, and Todd and Iler, though histological material showing the detail of the process is rare. In this series of cases, two fractures (Cases 113 and 138) in which biopsy specimens of the fracture ends were excised with callus, show that in the large long bones of adult man, the process of osteoclastic resorption of the uninjured cortex is largely confined to the inner walls of the shaft, and is more extensive at a distance from the fracture site than near the necrotic cortical ends. Lexer correctly correlated the "atrophy" of the fracture ends with the expansion of the blood supply at the fracture site, and interpreted his specimens as indicating that the rarefaction of the main fragments is the result of "lacunar resorption which follows hyperaemia".

VII. THE CHANGES IN THE CHEMICAL COMPOSITION OF THE BLOOD IN FRACTURE HEALING

As shown in Table I, the levels of serum calcium, inorganic phosphorus, and alkaline phosphatase activity, determined at various stages of fracture healing, reveal no consistent variation from the range of normal values for these substances in patients of various age groups. Also the individual levels of the serum calcium, phosphorus, and phosphatase cannot be correlated with the delay in calcification of the callus. The lag in calcification is seen during the period of most rapid growth of new bone, or until the callus reaches its maximum size, and may be regarded as characteristic of man under urban conditions and the modern diet.

The level of the serum phosphorus in young rats under ideal conditions for calcification of bone [100] corresponds to the level found in infants and young children, but is rarely obtained in older children and adults such as comprise this series of cases. The authors have examined undecalcified sections of the costochondral junctions of infants, and have found that there is no lag in the calcification of the growing bone, but they have not had the opportunity to study the calcification of the callus in babies. Also, no attempt has been made at parenteral administration of phosphate solution [101] in patients, although these experiments should be completed to arrive at a conclusive answer to the question of the relationship of the serum phosphorus to the volume of osteoid tissue or the delay in the calcification of the human callus. This question is pertinent in view of recent contentions that greater efficiency of absorption from the intestinal tract, reabsorption of secreted calcium, and percentage of retention of calcium and phosphorus, indicate that calcium is better utilized in the rat than in man.

A number of the patients listed in Table I were given approximately 1000 international units of vitamin per day for a variable period of time. This dose is not sufficient to produce an elevation of the serum calcium or phosphorus, and there is also no difference in the volume of osteoid in the callus in the patient given the cod-liver oil and in the patients on the unsupplemented regimen.

The observations recorded in Table I also indicate that ambulatory patients show approximately the same serum-calcium and phosphorus levels, and about the same quantity of osteoid in the callus as partially or totally immobilized patients. Similarly there is no indication that the type of orthopaedic treatment has any influence on the calcification of the callus. It may be concluded that increased excretion of calcium salt, associated with immobilization or atrophy of bone, is not responsible for the delay in calcification of the callus in man.

VIII. THE BLOOD SUPPLY OF THE CALLUS

The vascular system of the fracture site, like the callus itself, is a temporary development growing in size and complexity corresponding to the volume of the deposits of new bone, and is absorbed gradually in

the process of resorption of the callus. Lexer injected an opaque material into the vessels of bones with experimental fractures, and demonstrated that in the course of healing, a large collateral circulation developed at the site of the fracture all around the nutrient artery, transgressing all parts of the fracture ends enclosed in callus, and supplying the areas of new-bone formation with an intricate vascular network. Johnson showed by means of surgical excision of the periosteum on one hand, and blocking the medullary vascular pathways on the other, that the sub-

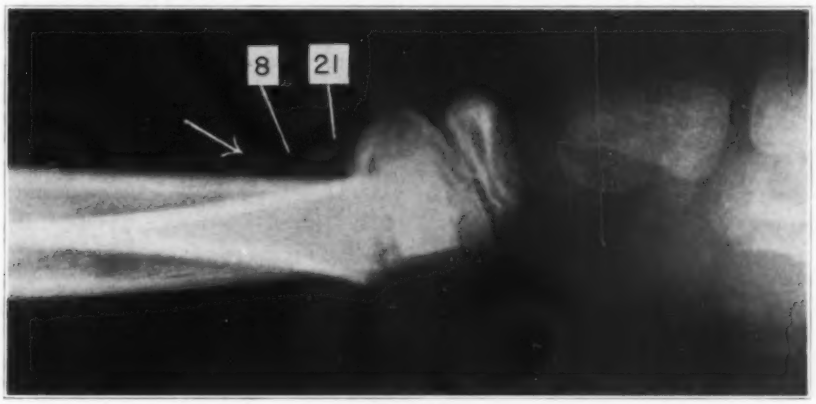

FIG. 19

Case 101. Roentgenogram of a Colles' fracture after twenty-one days in which the patient suffered a second injury after thirteen days of healing, and sustained a fracture of the callus. There are two fracture lines, that of the original injury (*21*), and that of the callus (*8*) as well. The arrow indicates the point at which the surgeon's osteotome cut the specimen shown in Fig. 20.

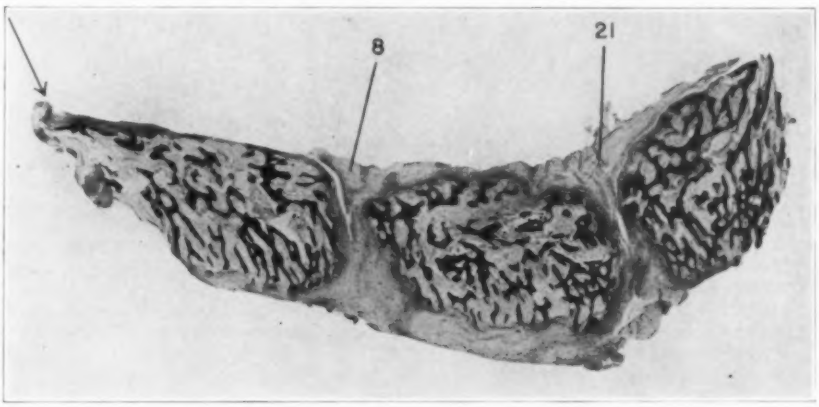

FIG. 20

Case 101. Photomicrograph (×14) of a section from a block of the external callus shown in Fig. 19. The arrow at the left corresponds to the line of the arrow in Fig. 19. The fracture line (*8*) contains granulation tissue characteristic of an eight-day healing fracture, and the fracture site (*21*) is filled with fibrocartilaginous callus in the process of replacement by bone. The latter is accomplished only later in the third week of healing. As shown here, the uniting of fractures through the solid surfaces of the bone of the metaphyses is by direct extension of parallel osteogenic fronts until bone meets across the fracture space.

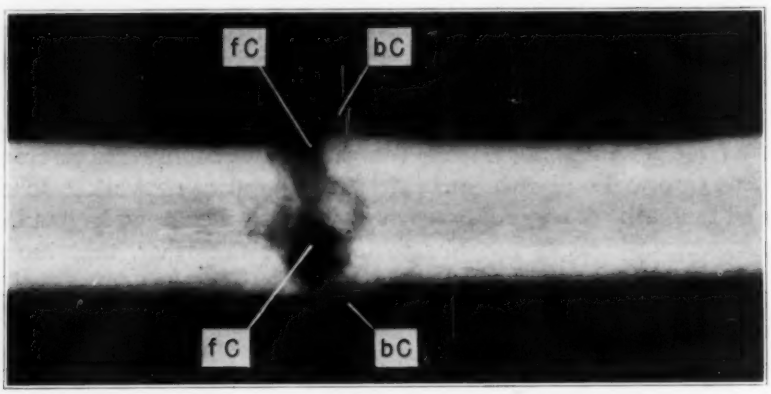

FIG. 21

Case 233. Roentgenogram of a fracture of the femur after thirty-three days of healing, showing a shell of bony callus (*bC*) enclosing the fracture site which is filled with the radiolucent tissue (*fC*) found histologically to be fibrocartilaginous callus. A cross section of the callus shows that the new bone grows from each fragment to form an arch over the fracture line, as illustrated in Figs. 22 to 28.

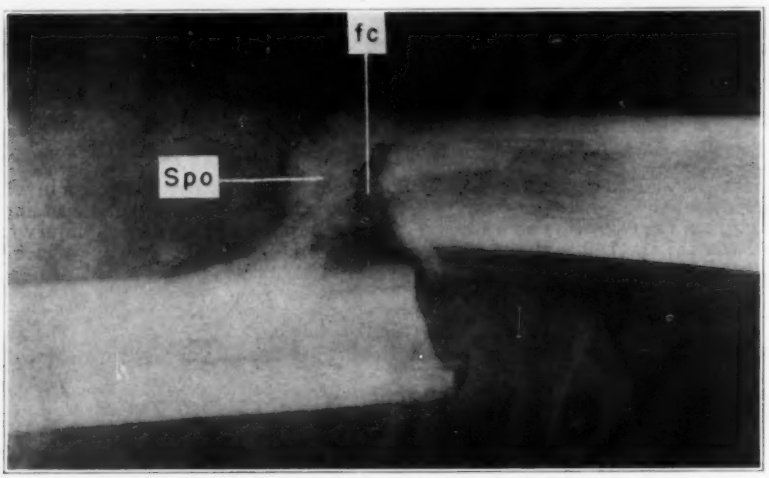

FIG. 22

Case 117. Roentgenogram of a fracture of the femur after ninety-five days, showing that the span of the arch is large when there is overriding of the fracture ends, and a wide space exists between them. Histologically it was found that the space (*fC*) contains fibrocartilaginous callus and interposed atrophied muscle, and the arch consists of densely calcified secondary spongiosa (*Spo*) which is growing down into the fracture gap by replacement of cartilage, fibrocartilage, and fibrotic muscle.

sequent infarction patterns indicate that a part of the blood supply of the external cortex is from the minute vessels of the periosteum, and indirectly also of the adjacent muscles. In fractures of the shaft, the callus is supplied by new branches of the nutrient artery, with the subperiosteal parts receiving, in addition, the smaller vessels (Fig. 9) from the periosteum. The latter are particularly important in the first week of healing, when the intramedullary part of the nutrient artery is ob-

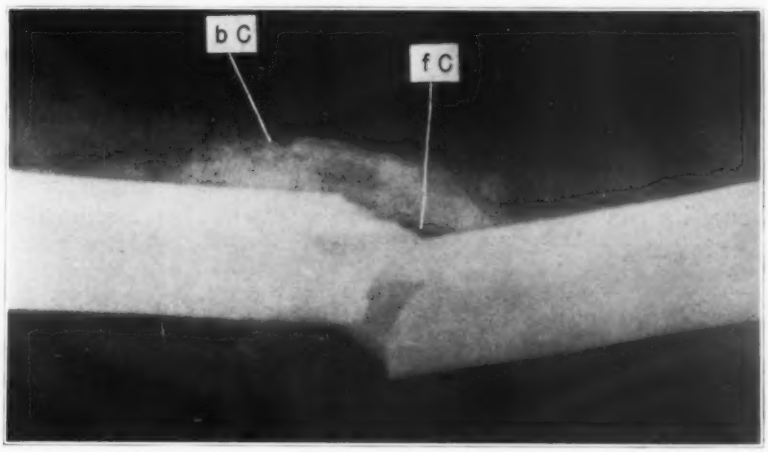

FIG. 23

Case 138. Roentgenogram of a fracture of the femur after twenty days, showing the extension of growth from the arch (*bC*) to the fracture gap by replacement of the fibrocartilaginous callus (*fC*). The differences in the rate of healing seen in the cases shown in Figs. 21 to 28 are due to differences in the ages of the individuals, in the position of the fragments, and in the volume of interposed injured tissue to be absorbed.

structed by the fracture hematoma or is interrupted through actual injury to the vessel, for ossification begins and is thus supported in the period that the medullary circulation is being repaired and expanded.

In fractures of the metaphyses, the blood supply of the callus develops at the onset of healing from the numerous metaphyseal perforating vessels, many of which, in man, are almost the size of the main nutrient artery. In addition, the terminary loops of the nutrient artery also branch throughout the cancellous bone. Thus the callus of fractures of the ends of the bones is supplied much more generously than the callus of fractures of the shaft.

It is of interest to note that in histological sections of the bony callus in the large long bones in man, dense trabeculae are oriented along the adventitia of the larger vessels to form a rigid system of tubes conveying the vascular channels through the tissues which cross the fracture gap, and are under continuous resorption and reconstruction.

IX. THE REACTION OF THE SOFT PARTS AROUND THE FRACTURE SITE

The acute inflammatory tissue developed in the injured soft parts, on the surface of the callus, and around the fracture site, becomes subacute and chronic in character and persists from the third week of healing until after the time of the uniting of the fracture. Perivascular round-cell infiltration, focal collections of lymphocytes and plasma cells, and occasionally lymphoid nodules are found in the intermuscular connective tissue and in the fibrous outer layer of the periosteum (Fig. 17). The lymphoid nodules, as typical as those developed in any lymphatic tissue

or described in the chronic inflammatory tissue of a variety of pathological conditions [68], show the outer corona of small lymphocytes and plasma cells and the germinal center of large lymphocytes and primitive connective-tissue cells (Fig. 18). The significance of this prolonged inflammatory reaction in the soft tissues of the injured extremity about the fracture site is not obvious, and, though probably not specific for injuries of bone, its relationship to the processes of callus formation deserves further investigation.

X. INTERPOSITION OF SOFT TISSUE

Interposition of soft tissue may be regarded as a normal feature of fractures of large long bones. Interposition, defined as displacement of both osseous and soft tissue adjacent to the fracture site occurred to some extent in all cases in this series. Marrow, bone, muscle, fascia, articular cartilage, capsular ligament, and no doubt also tendon and nerve in rare instances, are found in the fracture space and are absorbed as described in foregoing sections in the course of healing. Interference with the uniting of the fracture occurs only if the interposed tissue is viable and too great in volume to be absorbed in the period of expected consolidation. In several cases, flaps of muscle inserted into the fracture space were absorbed with difficulty; in contrast to other cases, in which isolated fragments of muscle without blood supply were absorbed readily. Numerous instances are cited in the literature in which segments of cortex were accidentally transfixed across the marrow cavity and engrafted in bony callus so as to seal the medulla. Union is not always retarded under such circumstances, as the authors have seen such fragments rapidly absorbed by "creeping replacement".

All complete fractures through parts of the bone upon which muscle is inserted, especially if the fragments are displaced, contain muscle in the callus. The muscle is readily incorporated in the new bone (Fig. 15), but there is no indication that the endomysial connective tissue is particularly susceptible to ossification. In numerous cases with malposition of the main fragments (Fig. 22), the histological picture suggests that interposed muscle is a barrier to healing. The muscle undergoing fibrous degeneration and the scar tissue remaining after the muscle fibers are absorbed, are penetrated and replaced by bone with difficulty, for the bone trabeculae become laid down parallel to the scar, and appear to increase in thickness rather than extend into the mass and advance the osteogenic front.

XI. THE RADIOLOGIC PROPERTIES OF THE CALLUS

When the roentgenogram and undecalcified histological picture of the callus are superimposed, it is clear that the x-ray shows little more than a silhouette of the denser calcium deposits in the fracture site. As calcium exists only in bone tissue, except for a microscopic layer of cartilage wherever the fibrocartilaginous callus comes in contact with

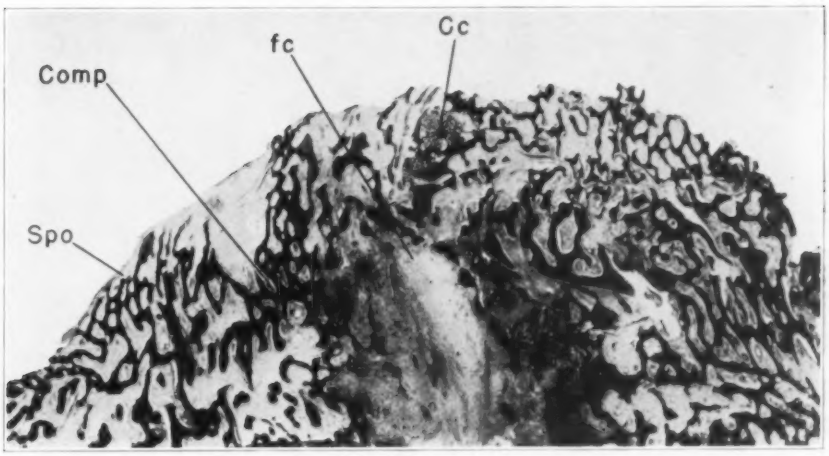

FIG. 24

Case 105. Photomicrograph (×11) of a section through the external callus of a thirty-day healing fracture. An arch of spongiosa (*Spo*) is formed over the fibrocartilaginous callus (*fc*). New compacta (*Comp*) is formed between the spongiosa and the fibrocartilaginous callus. *Cc* is a patch of calcified hyaline cartilage in the process of replacement by bone.

bone, *all radiopaque tissue is bone,* at all stages of healing. The procallus and the fibrocartilaginous callus, excluding fragments of isolated bone, are as radiolucent as muscle or other soft tissue (Figs. 19, 21, 22, and 23).

In general, in routine clinical roentgenograms, a part of the bony callus—the newly deposited spongiosa—is not visualized (Fig. 10), so that in the early stages of healing, exuberant bony callus may not be demonstrable (Table I: Cases 138, 141, 146, 147, 149, 193, 198).* This often accounts for the apparent discrepancy between the clinical finding of complete immobility of the fragments in the face of a negative roentgenographic examination for callus formation. Since the ratio of the thickness of the intervening soft parts to the density of the calcium deposits determines the results obtained with any single combination of kilovolts and exposure time, the new spongiosa of the callus of a superficial bone such as the tibia may be demonstrated while the same tissue cannot be shown in a fracture of the femur embedded in a large volume of muscle which scatters the rays and is as dense as poorly calcified osteoid.

XII. THE UNITING OF THE FRACTURE

It is evident from the first week after injury, as outlined in the foregoing description of the pattern of fracture healing, that the uniting of a fracture depends upon organized growth. The healing process is so coordinated that in succession, progressing centripetally into the fracture

* No special effort has been made to obtain uniform roentgenographic records of the callus in the cases reported here. Both portable and stationary equipment were used, and, as may be expected, pictures superior in every respect were received by the use of the latter, but the inability of the x-ray to outline the first deposits of incompletely calcified spongiosa is true of each machine as used in routine hospital work.

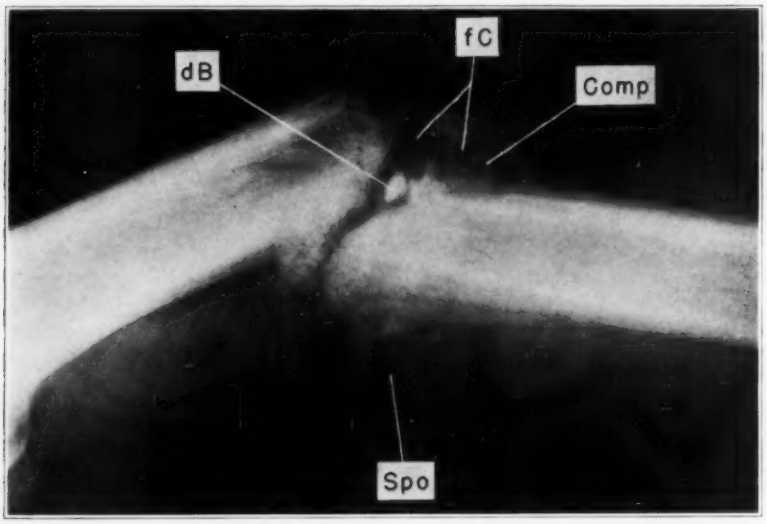

FIG. 25

Case 113. Roentgenogram of a fracture of the femur after eighty-five days of healing showing a spindle of bony callus enclosing the fracture site, but not yet joining the cortical ends which are still separated by fibrocartilaginous callus (*fC*). Spongiosa (*Spo*) and compact bone (*Comp*) are seen in a histological section through the lateral half of the callus shown in Figs. 26 and 27. An isolated fragment of dead cortical bone(*dB*) may be seen in the roentgenogram.

site, organizing hematoma and granulation tissue give rise to fibrocartilaginous callus, which in turn is penetrated and replaced by bone which grows into it from outside the fracture gap. For the replacement of the fibrocartilaginous callus, the various tissues are assembled according to two patterns, one observed in the uniting of fractures through solid cancellous bone, the other in fractures through the hollow shaft.

In fractures through the spongiosa of the ends of the bones, the pattern of union is simply that of two roughly parallel lines of bone formation advancing through the soft tissues across the fracture site (Figs. 20 and 21). If the fracture is reduced to anatomical position, there is no external callus and the area over which osteogenic tissue advances across the fracture gap is nearly the same as the injured surface area of bone tissue of the main fragments. Figure 4 of the paper of Kulowski and Luck shows an excellent whole-mount preparation of a united fracture of the neck of the femur, fifty-two days old, which is an excellent example of a situation in which, after ideal reduction, union may develop by the simple extension of the osteogenic front from the surface of one fragment to that of the other.

Union of fractures of the shaft develops from a relatively small surface area of bone, especially if the injury is nearly a straight-line transverse fracture. The spindle of bony callus forms entirely from the outgrowth of osteogenic connective tissue of the inner periosteum and the cancellous lining of the comparatively inactive cortex. Beginning

TABLE II

HEALING TIME FOR TREATED FRACTURES

Type of Fracture	Upper Extremity		Lower Extremity	
	No. of Weeks Required to Bridge the Fracture Gap	No. of Weeks Required to Repair the Cortex	No. of Weeks Required to Bridge the Fracture Gap	No. of Weeks Required to Repair the Cortex
Spiral or long oblique	3	6 to 12	6	12
Transverse	6	12 to 18	12	24

with a restricted mechanical foundation and this limited supply of cellular building material, a strict economy of design is utilized in the regenerative process. In cross section, this design is closely analogous to that of a fixed-arch bridge, and is evolved as shown in detail in the accompanying schematic illustrations (Figs. 28-A, 28-B, and 28-C). In both roentgenographic and microscopic pictures (Figs. 21, 22, 23, 24, 25, 26, and 27), the fracture ends are joined first by the construction of a spherical arch of bone over the fracture gap. Histologically, the arch consists of an outer ring of delicate new bone (primary spongiosa) and an inner zone of heavier trabeculations (secondary spongiosa) and lamellar bone (compacta) forming haversian systems around the retreating margin of fibrocartilaginous callus. The bone is finally deposited between the cortical ends in the form of compact bone by extension of osteogenesis radially through the remaining fibrocartilaginous callus from the bony arch to the fracture gap (Figs. 27, 28-A, 28-B, and 28-C).

The time of expected union * varies in different types of fractures of the shaft, mainly in the time necessary to construct the bridge of bone, which in turn depends upon the distance between the fragments and the surface area of the fracture line. The latter may be considered a quantitative index of the osteogenic cellular elements engaged in regenerative activity. In spiral fractures of the shaft, in which the area of the fracture line is great and the distance between the fracture ends is usually small, union occurs in one-half the time required to heal a transverse fracture through the same site. In comminuted fractures in which the area of the fracture line is greatly increased, the distances between the fracture line ends being equal, the healing time is less than that of a transverse fracture, and the same or longer than that of a spiral fracture. As Key and Conwell point out, exact anatomical reduction of fracture of the shaft is not advantageous for bone regeneration; this is shown by the fact that a larger

* The terms *united by calcified callus, consolidation, union, fibrous union, cartilaginous union, bony union* are found in the literature arbitrarily given special meanings. The authors' usage for the term union, here and previously [100], has been to designate the state of new-compact-bone formation between the fracture ends so as to repair the original shaft.

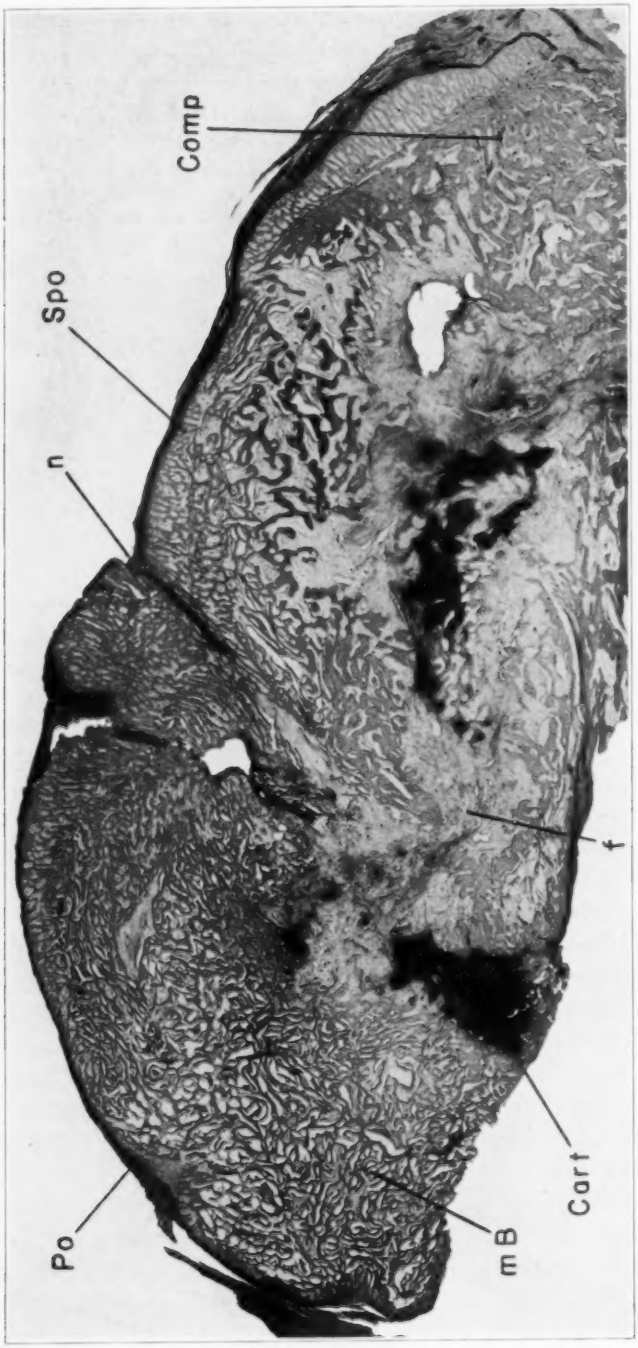

FIG. 26

Case 113. Photomicrograph (×4) of a section through the upper half of the callus shown in the roentgenogram in Fig. 25. The bony callus consists of an outer part of newly deposited spongy bone, seen in oblique section (*mB*) and longitudinal section (*Spo*), which is not sufficiently dense to be seen in clinical roentgenograms, and an inner part of denser cancellous bone and new compacta (*Comp*). The fibrocartilaginous callus shown here consists of cartilage and fibrocartilage (*Cart*), and dense fibrous connective tissue, and is an extension of the fibrocartilaginous plate between the fracture ends; it is entirely radiolucent. *Po*, periosteum; *n*, notch in the surface of the callus serves to orient the reader in the examination of Fig. 27. Hematoxylin, eosin, and azure stain.

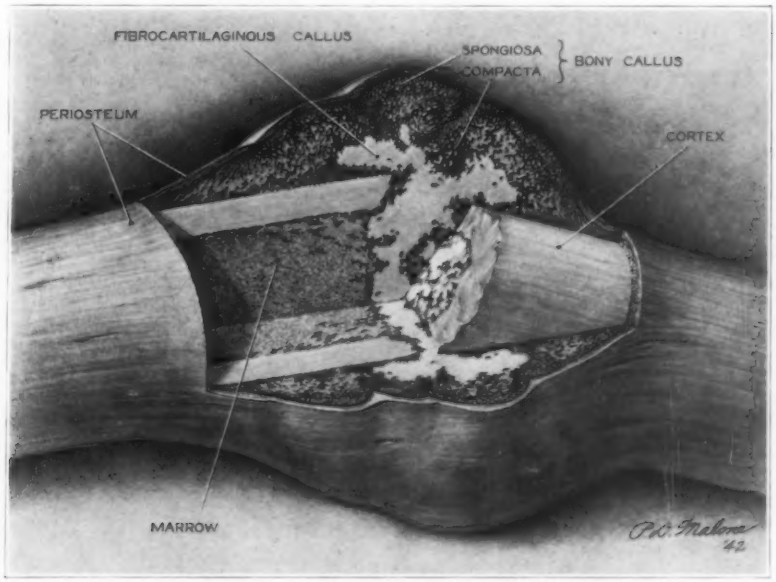

FIG. 27

Case 113. Artist's reconstruction of the fracture site, drawn from a clay model of the roentgenograms of the case shown in Figs. 25 and 26. Histological sections of various parts of the callus were placed on the appropriate plane of the sectioned surfaces and reproduced as magnified (×1⅓). The notch in the periosteal surface of the callus overlying the fracture line corresponds to the point, *n*, in Fig. 26. In the gross, the cartilage, fibrocartilage, and dense fibrous connective tissue of the fibrocartilaginous callus are seen as a homogeneous, glistening, white scar between and about the fracture ends.

volume of bony callus or uniting surface is developed when 50 per cent. or more of the surface of the fracture ends are in contact.

The time table of Perkins, as modified in Table II to fit the microscopic picture, is an accurate and simple schedule of healing for general purposes, and holds approximately true for the authors' cases. For its prognostic use, it is necessary to consider and correct for variable factors such as *overlap* or *angulation of the fragments, separation of the fracture ends by traction or muscle pull, injury or excision of tissue outside and inside the fracture site by open reduction or internal fixation, anatomical details such as the blood supply of the individual bones, infection*, and general conditions, such as *age*, and *concomitant pathological states*, such as arteriosclerosis, which ordinarily are compatible with the process of complete repair of bone.

XIII. DISCUSSION

There is complete similarity in the organization and composition of the callus in man and in the laboratory rats which have been employed previously in experimental studies [100]. In both man and animals, separation, displacement, angulation, or motion of the fracture ends have been shown conclusively to lead to the formation of a large volume of callus and

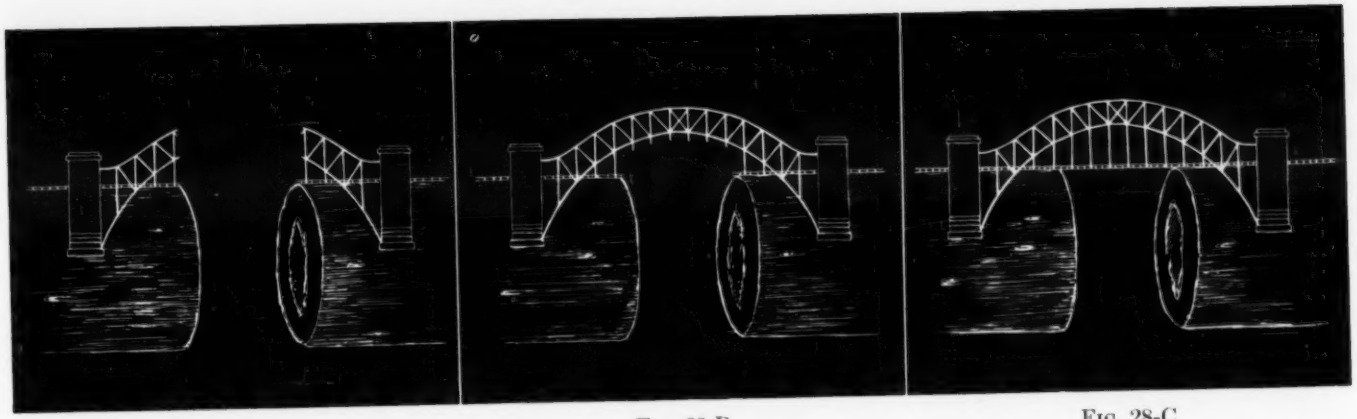

FIG. 28-A FIG. 28-B FIG. 28-C

Schematic drawing of the design of the Hell Gate Arch, New York City, 1917.
The processes of the development of union as illustrated in cross section in the previous histological and roentgenographic pictures, are clarified considerably by the mechanical analogy of the construction of a fixed-arch bridge.

Fig. 28-A: *Bridge, Stage 1.* A tower or elevated abutment is constructed on each embankment of the gap to be spanned, as shown in the figure on the left.

Fracture, Stage 1. New bone is deposited on the cortex on each side of the fracture line as shown in Figs. 8 and 9.

Fig. 28-B: *Bridge, Stage 2.* By the method of cantilevering out, an arch is constructed over the gap.

Fracture, Stage 2. New bone from both fragments grows over the fracture line, and not between the main fragments, until the fibrocartilaginous callus is penetrated, resorbed, and ossified, as shown in Figs. 21 to 27.

Fig. 28-C: *Bridge, Stage 3.* The deck of the bridge is laid down between ribs and spandrils suspended from the arch, and is the last part to be constructed.

Fracture, Stage 3. New bone showing the formative structure of the haversian systems of the compacta, appears between the arch of spongiosa and the cortex and continues to develop directly from the new bone replacing the last remnants of the fibrocartilaginous callus between the cortical ends. The new bone finally laid down between the cortical ends thus grows from the arch of spongiosa and the subperiosteal cancellous bone deposited on the cortex for some distance from the fracture gap (Fig. 27). There are no isolated areas of bone formation which appear to be spontaneous or metaplastic in origin.

the development of an excess of cartilage between and about the fracture ends [94, 51]. When some effort is made to prepare experimental fractures of the shaft of the long bones to correspond in type, alignment, and fixation to clinical fractures, the volume of cartilage and the configuration of the callus is found to be essentially the same, regardless of the species of animals [51]. However, the authors' observations have shown that human accidental fractures subjected to the modern orthopaedic treatment differ from prepared experimental fractures in animals under ideal nutritional conditions in two respects: (1) injury and interposition of surrounding soft parts, and (2) delay in calcification of the new bone in the early stages of callus formation.

The Significance of the Organizing Blood Clot

Bier [7], one of the early modern writers to emphasize the rôle of the fracture hematoma as the "stimulating" factor in callus formation, recanted this view after further consideration of the works of his contemporaries [60, 38, 86], and concluded finally that "chronic irritation of necrosis and hemorrhage" promoted new-bone formation. The influence of Bier's writings is seen in the reports of a large number of investigations [9], and is carried farther in the recent works of Murray [75], Stirling, and many others who ascribe particular properties, such as high acidity, high calcium content, and hypothetical enzymes, to the organizing hematoma of an osseous wound. Undecalcified preparations of both experimental and clinical fractures, however, have not demonstrated calcification of the hemorrhagic substance, which suggests that the high calcium content of the blood clot is simply due to the included microscopic particles of dead bone, rather than to any biochemical property peculiar to the fracture hematoma. Whether or not the pH of the hematoma fluid is low in the first five days of healing [75, 97], at this time it is not possible to demonstrate decalcification of either living or dead bone, or solution of calcium salt selectively through increased acidity in a "closed chemical factory" [97] as might be shown *in vitro*. Absorption of injured bone has been described in detail, and the evidence is that the calcium salt so mobilized is carried into the circulation and is not redeposited locally [102] as various authors assume [97, 73, 74].

Injury, Interposition and Absorption of the Various Tissues at the Fracture Site

Paget wrote in 1854, "The injury inflicted in the fracture of a long bone is rarely limited to the bone. The two or more fragments, driven in opposite directions, penetrate the adjacent tissues, wounding and bruising them, and giving rise to bleeding of various amount. . . . It is not infrequent, in recent fractures, to find portions of muscle and other soft parts completely crushed by the bones. . . ." It has been emphasized that this is characteristic of fractures of the large long bones. The authors have described fragments of injured muscle, marrow, fascia,

capsular ligament, articular cartilage, and bone of various sizes, and the details of their absorption in the fracture site. Absorption is accomplished by cellular activity rather than by simple chemical solution.

Many of the fractures listed in Table I were inadequately aligned, and almost all were subjected to closed manual reduction. The exact amount of manipulation is not known for most of the cases, but it may be assumed that the manual disturbance to the fracture site was considerable in a large number of the patients. One group of fractures of the shaft of the large long bones were treated initially with a Thomas splint or one of its modifications, and were relatively undisturbed. Interposition of tissue was found in both manipulated and untouched cases, *but large quantities of microscopic fragments of isolated injured tissue were characteristic of the treated fractures*, and were especially abundant in fractures of the ends of the bones which required numerous attempts to improve reduction. It may be assumed that the same forces required to align the fragments draw and crush soft tissues between the fracture ends and scrape off particles of spongiosa. As would be expected, it was found that comminuted displaced fractures are produced with more damage to adjacent soft tissues. The absorption of interposed necrotic tissue proceeded rapidly within the spindle of callus, and did not interfere with the essential processes of healing in any of the cases presented here. Massive interposition of viable fragments of injured soft parts was seen in all cases with extreme malposition, and in many of the cases eliminated from this series as examples of delayed or non-union. It may be assumed, safely, that this disrupts the organization of the callus and interferes with the uniting of the fracture.

It has been found that all complete fractures through portions of the shaft upon which muscle inserts [88] contain muscle tissue in the callus. The fate of this tissue is absorption, as observed by Ollier, though the muscle was seen in the form of necrotic fragments which disappear rapidly, and vascularized flaps which persist for sometime and slowly undergo typical fibrous degeneration. This has also been demonstrated experimentally in the recent work of Dengler. The only reliable clinical sign for interposition of soft parts is retraction of the skin overlying the fracture site.[89, 9] Neither the necrotic nor the atrophic muscle appears to calcify, though the connective tissue between the larger muscle bundles has been observed to be replaced by bone in many instances. Histological sections from ten recent cases of myositis ossificans conscripta on file in the Pathological Laboratory of the Johns Hopkins Hospital show pictures resembling muscle incorporated in the callus of fractures, in that the endomysium and perimysium are ossified, while the muscle cells atrophy and hyalinize. The chronic inflammatory reaction, such as is seen in the muscle, fascia, and scar tissue surrounding the callus of almost all normal fractures, is not present in myositis ossificans. The question arises as to whether this persisting inflammation is the factor which delimits the area of callus formation, or whether it simply represents

prolonged reaction to injury of the tissues contused by the fracture and later compressed by the expanding callus.

Fragments of dead bone have been described in the fracture hematoma as microscopic fragments, many of which are assumed to have arisen in manipulation of the fracture, in addition to the gross segments of the shaft such as John Hunter observed: "Adhesion of the detached splinters takes place, interstitial absorption making them softer, and less pointed; and this takes place not only in those which are attached to soft parts, but even in such as are entirely loose. (This was shown in the thigh-bone, in which one of the splinters had turned quite around on its axis, and adhered by its outer surface to the bone.) Therefore these pieces must retain the living principle, and probably only this, while those that remain attached have more. I never examined a compound fracture without finding some of these loose pieces, which shows they must be common." The conclusions reached through microscopic examination of the fracture site testify to Hunter's faculty of interpretation in distinguishing between the activity of isolated and attached fragments. Most of the bone fragments are inactive, and some are buried in the substance of the hematoma for several days to weeks before organization of the fibrin is completed. A few particles located on the surface of the blood clot in contact with the marrow cavity react like the transplants in soft tissue reported by Phemister [82], Davis and Hunnicutt, and Gallie and Robertson, who agreed that in some instances lamellae of new bone develop on the surfaces of the dead matrix through the proliferation and differentiation of the surviving osteogenic connective tissue contained in the bone. When new bone grows into the fracture gap and encounters the dead fragments buried in the developing fibrocartilaginous callus, absorption takes place with engraftment of the old bone in the new bone by the process of "*schleichender ersatz*" or creeping substitution of Marchand.

From the above observations it may be concluded that the blood clot is not a culture medium for the connective-tissue outgrowth of isolated bone fragments, but suitable conditions are seen in granulation tissue if the particle has not been separated from blood supply in unorganized fibrin for a long period of time. In addition to paucity and death of active cells in the fragments, isolation from the body also diminishes the osteogenic potency of the outgrowth of connective tissue of transplanted bone [40].

The histochemical methods employed here have demonstrated new details of the processes of absorption of dead bone, particularly of the mobilization of the content of bone salt. In the inflammatory tissue of the procallus, the dead bone is decalcified and absorbed simultaneously and shows crystalline surface patterns in silver staining of the bone salt. In granulation tissue, the same process occurs by *granular crumbling*, in which fine particles of bone are eroded from the surfaces of the fragment and dissolved. Later, in dense fibrous connective tissue, the remaining bone fragments may be decalcified in advance of disintegration of the bone matrix. This is the only instance in which *in vivo* bone is decalcified,

removing the calcium salt and leaving the matrix intact, as was postulated by the old concept of halisteresis of von Recklinghausen. Until organization of the fracture hematoma, the particles of bone in it remain inert, suggesting that absorption of the dead bone is accomplished by cellular activity. In "creeping replacement" of the dead bone by new bone, there is no preliminary decalcification of the former, and in silver staining, the latter does not appear to be laid down more densely calcified than the trabeculae elsewhere in the callus. Thus there is no local transfer of bone salt from dead bone to new bone, as occurs from living cortical bone to new subperiosteal bone as described previously [102]. These differences in the appearance of the process of absorption of dead bone through the different stages of healing may be related to changes in the chemical composition of the intercellular fluids, though as yet little or nothing is known of this subject pertaining to bone.

Fracture Healing and Mineral Metabolism

The origin of the new bone remains the outstanding problem in the study of the physiology and repair of bone. After three centuries of research reviewed by Ghormley and Stuck, the investigation of this problem has finally departed from experimental attempts to separate the osteogenic tissue from the bone surgically. The history of classic debate on the rôle of the periosteum in bone repair culminated in the anatomical problem of allocating the cambium layer of bone-forming cells to the periosteum or to a sheath of the bone, as it is now generally accepted that everywhere the bone tissue is lined by cells which are known to possess osteogenic potency. In rapidly growing osseous tissue, these are the highly basophilic, polygon-shaped cells with a prominent Golgi net in the nucleus recognized as the typical osteoblasts. In areas of the bone in which growth is relatively slow, the cells lining the trabeculae are spindle-shaped and resemble fibroblasts or the reticular cells of the lymphatic tissues, bone marrow, or reticulo-endothelial systems. Bloom, Bloom, and McLean have found particularly suitable material for demonstrating the histogenesis of osteoblasts from such spindle-shaped cells in medullary bone formation in birds. Prior to the maturation of the ovarian follicle, the endosteum consists of spindle-shaped cells which are termed "resting osteoblasts" on a functional rather than morphological basis because, although they resemble ordinary reticular cells or fibroblasts, they demonstrate osteogenic potency immediately in response to the humoral stimuli developed during the preovulatory phase of the egg-laying cycle.

These observations may be carried over to the situation in healing fractures with the understanding that under such conditions new-bone formation is the reaction to a different stimulus, that of injury. Howship's observations in 1818 on gross specimens and crude sections examined with the use of the solar microscope, and the observations of many others after him (see review of Ghormley and Stuck), have demonstrated conclusively that the new bone is derived from osteogenic cells within and

around the main fragments. To this fact it may now be added that spindle-shaped cells in apposition with the bone tissue respond to the injury by proliferating, and developing an increasing basophilia and prominence of the nuclear features until they become osteoblasts which lay down the new bone. The osteogenic potency of undifferentiated connective-tissue cells, fibroblasts, or reticular cells, appears to be relative to the proximity of the tissue to bone. The new bone grows along a front in which the osteogenic principle may be carried by proliferating osteoblasts to other mesenchymal cells. What constitutes the osteogenic stimulus and how ectopic bone formation is reconciled with the above observations remain unknown.

The works of the contemporary Scandinavian investigators, Levander and Annersten, have brought forward an osteogenically active extract of bone, the existence of which has been postulated [7, 8], claimed [59, 18, 29, 107, 41, 1, 10, 19], and doubted [95, 54]. Levander's and Annersten's extract differs from those of previous writers in that it is obtained by fat solvents, and, if injected intramuscularly, will produce typical ectopic bone formation. This work, if confirmed, suggests that the osteogenic local factor emanates from injured bone.

Schmidt in 1898 reviewed the older literature on the cartilage in fracture healing and the factors influencing chondrogenesis in the callus, to which very little has been added except substantiation [55, 37] of the theory that mechanical stress promotes the differentiation of connective tissue into cartilage through interference with the blood supply and nutrition of the cells. That this theory is not altogether satisfactory as an explanation for chondrogenesis is seen in the regularity with which cartilage appears in tissue cultures and culture transplants, whether or not pressure or tension is applied to the cells. Clark and Clark, observing cartilage formation in the living animal with the use of improved chamber techniques, show that reduction of the vascular network of the tissue follows rather than precedes chondrogenesis. This is also the picture in the early callus where cartilage begins to form in highly vascular granulation tissue before the blood supply is condensed by the formation of the intercellular substance of dense fibrous connective tissue. The cartilage is formed mainly in and around the fracture gap, but in clinical fractures it is also found in small islands embedded in the subperiosteal deposits of bone. The authors' view is that mesenchymal or reticular cells, whether in the granulation tissue of the organizing hematoma, periosteum, or endosteum of the bony callus, possess the potency to form cartilage under certain conditions and bone under other conditions. The cartilage is ultimately replaced by bone which grows into it along the osteogenic front containing osteoblasts, but the fate of the chondrocytes in the variegated histological picture of intracartilaginous ossification is not clear.

Calcification of the callus occurs simultaneously with ossification in animals under ideal conditions, and no preliminary stage of osteoid tissue is necessary for bone formation, as was believed formerly [100]. In im-

mobilized fractures in urban and rural patients on modern hospital diets considered adequate in every respect, the authors have found considerable lag in the calcification of the new bone. Osteoid tissue in abundance equivalent to a moderate state of rickets was demonstrable throughout the growth of the callus. After the callus reached its maximum volume, the rate of ossification diminished, and resorption and reconstruction of the existing new bone through formation of osteoclasts and osteoblasts became more apparent. In this process there is probably a local redistribution of the calcium [102] as well as reinforcement of the supply of mineral by way of humoral transportation, with the result that calcification of the bony callus becomes nearly complete at the time that the fracture approaches union.

The temporary delay in calcification of the callus may be explained on the grounds that mineral metabolism of the adult human is not immediately adjustable to the rapidly inflicted burden of fracture healing upon the calcifying mechanism. This is to say that for ordinary replacement of bone tissue lost by bone resorption, to preserve the density of the skeleton, calcification proceeds readily without appreciable delay, if the levels of the blood calcium and phosphorus are maintained by both the readily available metaphyseal bone stores and the continuous absorption from the intestinal tract. The rachitic picture of abundant osteoid develops only in the callus because elsewhere bone growth is relatively slow and the supply of mineral is ample to support complete calcification of new bone. With respect to the callus *per se*, the situation is thus the same as in the rats described by Pommer, which led him to the erroneous concept of the "physiological osteoid", because the dietary calcium, phosphorus, and vitamin D were sufficient for growth and reproduction, but inadequate for optimum storage of bone salt in the skeletons.

The data in Table I corroborate the finding of the majority of investigators that, during fracture healing, the level of the serum calcium does not change [102], and that the serum phosphorus remains so low that it is difficult to account for calcification on the basis of the solubility of the phosphates of calcium. For calcification of the callus, as applied to calcification of the skeleton in general, local factors must be postulated to speed the reaction between Ca^{++} and $PO_4^{\equiv}$ or Ca^{++} $CaHPO_4$ and $PO_4^{\equiv}$ in the tissue fluids of the new bone.[65] Considerable evidence exists to show that hydrolysis of organic phosphates by an enzyme phosphatase, may accomplish this by increasing the concentration of phosphate ion locally, but much is lacking for the demonstration of this mechanism under physiological conditions.

Numerous investigations have shown that the level of the serum basic phosphatase activity undergoes little [44, 16, 80, 91] or no [16, 70, 58, 99] change during the healing of fractures, which are corroborated by the data in Table I, but, as in all rapidly growing spongiosa, the concentration of the tissue phosphatase in the callus is greater than in uninjured relatively inactive bone tissue [62, 16, 105, 101, 99]. It is noteworthy that the serum

phosphatase does not increase during the rachitic phase of callus formation as occurs in systemic rickets, though this may be explained by the relatively small source and the factor of dilution.

Ossification proceeds and union develops at the appointed time regardless of the lag in calcification of the new bone laid down throughout the period of the most rapid growth of the callus. The fact that incomplete calcification of the new bone does not delay union may be regarded as the explanation for the apparent ineffectiveness of treatment to accelerate union by means of mineral supplements or pharmacological agents such as vitamin D or parathyroid hormone, although there is considerable evidence to show that such measures improve the density of the callus [50, 71, 43]. The uniting of the fracture is the end result of various growth and regenerative processes of which calcification and ossification are structural products. Measures which improve the density of the bony callus do not necessarily also promote, but may actually inhibit [63] the healing of a fracture through their influence on the preliminary phases of regenerative process.

The Mechanics of Union

The preceding observations and illustrations have shown that the development of the callus follows an organized pattern which is present from the first week of healing. Some difference in detail of the pattern is found at the time of union in fractures of the hollow shaft and of the solid surface of spongiosa of the ends of the bones. In fractures through the metaphysis, the bone unites by the simple process of direct extension of bone growth from the injured surface of the fracture ends, without any preliminary formation of external callus (unless displacement or angulation was present to necessitate the construction of a bridge of bone across the shortest distance between the main fragments). The uniting of fractures of the shaft is more complicated, and is accomplished in two stages which are readily seen in cross sections of the callus of the fractured femur between fifty and 100 days of healing: (1) A spindle of external *bony callus* is formed around the fracture site, enclosing the cortical ends while they are still separated by fibrocartilaginous callus; (2) *compact bone is deposited directly* through the new bone which grows inward from the outer shell of bony callus and replaces the last remains of the fibrocartilaginous callus. The dynamics of this process has been illustrated by the analogy of the stages in the construction of a fixed-arch bridge (Figs. 26, 28-A, 28-B, and 28-C), in which it may be seen that the original osteogenic surface or foundation of the callus is enlarged to develop the broadest and strongest possible surface of new bone at the line of union.

The structural lines of the united fracture have been described by Wolff, Wehner, Bessler, and others, and all have emphasized the correlation between the lines of stress and strain and the architecture of the new bone. Zondek recognized the "early structural orientation" in healing fractures, and Koch corroborated this observation, but concluded

that the morphogenesis of the callus and the uniting of the fracture cannot be relegated simply to the enforcement of Wolff's Law. The authors have observed that the various forces imposed upon the fracture site through a variety of different forms of orthopaedic treatment—that is, traction, immobilization in neutral or other positions applying stress at the fracture ends—did not result in any variety in the organization of the callus or the dynamics of union. As is readily seen in the roentgenograms [51, 93], the outline of the spindle of bony callus always corresponds to the position of the fragments and the relationship of the soft parts in the particular area of the fracture. After consideration of these observations, the authors' view is that while Wolff's Law explains the adaptation of the architecture of bone to the pressure and tension exerted through its structure, the course of bone regeneration is not directed by mechanical forces. As is well known, fractures will unite solidly in patients in bed, who have had no opportunity to use or bear weight upon the injured part.

XIV. SUMMARY: A RÉSUMÉ OF THE PROCESS OF HEALING OF CLINICAL FRACTURES

Immediate

The immediate effect of a fracture is rupture of the continuity of the osseous tissue with extravasation of blood which does not clot entirely for from several hours to the end of the first day. If the fragments are displaced, as necessarily occurs in the initial injury when the fracture is complete, it is common to find contusion and laceration of muscle, displacement of fragments of bone, bone marrow, muscle, fascia, and, rarely, compression of tendon and nerve between the cortical ends. In fractures through the ends of the bones, pieces of articular cartilage and capsular ligament may be dislodged and displaced into the fracture gap and included in the hemorrhagic tissue.

At the Time of Orthopaedic Treatment

The handling of a fractured limb in the course of clinical treatment and the manipulations necessary for reduction, produce further motion and friction at the injured surfaces of the bone and additional hemorrhage, dislodgment, and displacement of fragments of the various tissues at the fracture site. However, such evidence of secondary injury produced by treatment is mainly histological in uncomplicated cases.

In from One to Forty-Eight Hours

A septic inflammation occurs in all of the injured tissues at the fracture site. Organization begins in the interstitial blood clots in the injured bone and soft parts, and on the surface of the hemorrhagic mass in the fracture gap.

In from Two to Thirty Days

The hemorrhagic mass is encapsulated in granulation tissue which becomes fibrous connective tissue; as layer on layer of the blood clot

become organized and replaced by granulation tissue, the outer parts, developing into fibrous connective tissue, also show differentiation of fibrocartilage and hyaline cartilage. The fragments of dead soft tissue and bone, including the necrotic cortical ends, are absorbed in various ways characteristic of the different histological structures of each tissue. A certain amount of interposed soft tissue is common in fractures of the large long bones, and usually is absorbed without interfering with the essential processes of bone regeneration.

Four Days to the Time of Union

Intramembranous new-bone formation arises between the periosteum and the shaft, and upon the cancellous bone lining the marrow cavity, forming collars of bone on the medullary and on the periosteal surfaces of each fragment for some distance from the fracture line. The new bone originates in the proliferation of spindle-shaped cells in the inner periosteum and in the endosteum, which resemble fibroblasts, but which are termed "resting osteoblasts" because they exhibit increasing basophilia and growing prominence of the nuclear Golgi net, as they differentiate into true osteoblasts and bone cells. In fractures through the metaphysis of the bone, osteogenesis begins from the endosteum of the entire surface of injured cancellous bone as early as the third or fourth day. In fractures of the shaft, new bone is found subperiosteally between five and ten days, usually earlier than this in very young individuals and later in the aged.

The new bone calcifies completely, incompletely, or not at all as it is laid down in different parts of the callus, but in general, there is considerable delay in calcification with the result that osteoid tissue is abundant in histological sections of fractures in young individuals and adults on modern diet. After the callus reaches its maximum size, the existing osteoid is rapidly calcified and nearly all further new-bone formation occurs simultaneously with calcification. Osteoid borders are almost always demonstrable in the callus, but this may not be interpreted that a stage of osteoid is necessary for osteogenesis or callus formation. The routine clinical roentgenogram of the fracture site does not show the new bone for some time after it is deposited or until it increases in density, and throughout healing, regardless of the state of calcification, the newly deposited spongiosa outlining the callus is not much more dense than the large muscles around it.

Chondrogenesis takes place mainly between the fracture ends, and results in the formation of a disc of fibrocartilaginous callus consisting of dense fibrous connective tissue, fibrocartilage, and hyaline cartilage. The disc of fibrocartilaginous callus extends outside the fracture ends, separates the deposits of new bone on the fragments on either side of the fracture line, and occupies the clear space of the fracture gap when viewed in the roentgenogram. In addition to the main mass, small islands of hyaline cartilage may be seen histologically almost anywhere in the mass of the bony callus.

Ossification of the dense fibrous connective tissue of the callus is accomplished by simple intramembranous-bone formation. The fibrocartilage and hyaline cartilage are replaced by bone in a variety of ways whereby:

1. Bone is laid down on calcified matrix of previously invaded cartilage forming primary spongiosa;

2. Resorption of cartilage and deposition of bone occur simultaneously;

3. Immature hyaline cartilage and fibrocartilage are included and calcified in bone trabeculae, resorption being delayed;

4. Apparent transformation of chondrocytes into osteocytes is seen with the structure of the bone trabeculae.

Cartilage matrix calcifies superficially wherever it comes in contact with osteogenic tissue. Only the intercellular substance of bone and cartilage in the callus is capable of calcification, for, except for rare instances of calcified, hyalinized dead fragments of soft parts undergoing absorption, all other tissue, including the original hematoma, is replaced by bone without preliminary or intermediate deposition of calcium salt.

A large part of the shaft enclosed in callus is resorbed by the formation of osteoclasts, osteoblasts, and spindle-shaped cells which are by-products of the bone. Bone salt is transferred from the shaft to the callus in this process, but this source is slowly developed and submits only a very small contribution to the total calcium deposited in the fracture callus at any one time.

The new bone calcifies almost entirely through the deposition of calcium and phosphate ion, and, presumably also, primary calcium phosphate transported by the blood plasma and the intercellular fluids. The delay in calcification of the new bone deposited in the early stages of healing may be explained by the observations that the rate of osteogenesis is greater than the rate at which the calcification mechanism operates with the level of the serum calcium and the particularly low level of the serum phosphorus found in individuals other than infants and very young children. Calcium salt mobilized from necrotic or transplanted bone does not diffuse interstitially in form prepared for redeposition in new bone, and is carried out into the general circulation.

The levels of activity of blood calcium, phosphorus, and alkaline phosphatase are not elevated significantly during fracture healing.

The injured soft parts about the fracture site become scarified rapidly, but also show a prolonged inflammatory reaction throughout healing and after the fracture is united. The outer periosteum, the perimysium, and muscle, compressed by the expanding callus, exhibit perivascular round-cell infiltration and formations of lymphoid tissue and lymphoid nodules.

The various processes listed above continue simultaneously in different parts of the callus in a pattern of extremely irregular appearance, but are so organized that successively granulation tissue replaces hematoma; fibrous connective tissue, fibrocartilage, and cartilage supplant granulation

tissue; and bone from either fragment grows into the whole mass of fibrocartilaginous callus between the fracture ends. Union occurs when the growth of bone projected from one fragment meets that from the other and is reorganized between the cortical ends so as to repair the shaft.

The chronological sequence of the foregoing events is approximately the same in fractures of any normal bone. The exact time of their appearance including the development of union varies considerably with (a) individual bones, (b) age of the patient, (c) type of fracture, (d) the site of the fracture—metaphyseal or diaphyseal—(e) amount of displacement of the fracture ends, (f) volume of interposed fragments of injured tissue, and (g) general constitution conditions,—nutritional and subclinical pathological states.

The blood supply of the callus consists of new vessels derived from the subperiosteal and metaphyseal perforating arteries and the nutrient artery, which develop temporarily and acquire size and complexity corresponding to the volume of the bony callus.

At the Time Union is Developed

Fractures through the spongiosa of the metaphysis show direct extension of bone growth behind parallel osteogenic fronts advancing from the injured surfaces of the fragments.

In fractures of the shaft of a large long bone, and at all sites where non-union is common, a special course of growth is observed. In cross section, this has been shown to follow the mechanical requirements of the design and dynamics of a fixed-arch bridge. Before compact bone is deposited between the fragments, an arch of external bony callus is developed over the fracture gap. The fracture is united when new cortical bone is formed by growth extending centripetally from the external callus to the bone ends in the same way that the deck of a bridge is laid from the arch.

After the Fracture is United

The external and intramedullary bony callus is resorbed gradually as the bone laid down between the cortical ends reaches the density of the original shaft. After several months to a year the defect in the original bone is often so flawlessly repaired that the site of the fracture cannot be found.

XV. CONCLUSION

A new résumé of the process of fracture healing is presented which differs from the several others in wide use in the teaching and in practical literature, in that it is based upon direct examination of a large series of normal clinical fractures with the use of improved microtechnical methods, and in that it includes:

1. The concept of the organization of the callus;

2. Precise localization of the calcification in the histological and roentgenographic pictures of the callus;

3. Description of the process of removal of displaced fragments of injured parts and the significance of interposition of the tissues at the fracture site;

4. An analysis of the dynamics of union.

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DELAYED UNION AND NON-UNION *

Ninety Per Cent. Preventable

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Inadequate treatment, and not predisposing factors peculiar to the patient, the authors have found to be the cause of over 90 per cent. of delayed unions and non-unions occurring in fractures of the shaft of long bones in adults. Such a statement is at first hard to believe, and even more embarrassing to accept. Yet its truth cannot be denied, if one but has the courage to review critically all the circumstances surrounding each case within his own experience.

Such an honest analysis will lead to the inevitable conclusion that the large majority of non-unions are a result of failure to adhere closely to the three basic *A*, *B*, *C's* of fracture treatment:

A: Reduction,
B: Immobilization,
C: Preservation of blood supply.

A. NON-UNION FROM FAULTY REDUCTION

Reduction to be successful must be *sustained,* not only for the first week or two, but throughout the whole convalescence. If direct interfragmental contact is not maintained throughout the healing period, delayed union or non-union will result. The errors in reduction which the authors have found to be the most frequent causes of delayed union or non-union are discussed below.

1. *Failure to Achieve Apposition*

No one questions the fallacy of expecting early union when the fragments are not even approximated. Nevertheless, many reductions are checked by only a one-view roentgenogram.

2. *"Continuous" Traction*

Loss of reduction from improper traction is a prolific source of later grief. Skeletal traction has been a great boon, but its overzealous use has contributed greatly to non-union, especially in cases of transverse fracture. To be convinced of the deleterious effects of uncontrolled traction, one has only to review the end results of treatment prior to the popularization of methods of "continuous" traction. During this earlier period, while malunions of shaft fractures were plentiful, non-unions were the exception. Now the reverse holds true.

* Presented in part at the Annual Meeting of The American Academy of Orthopaedic Surgeons, 1942.

FIG. 1-A FIG. 1-B

Case 1. Mr. J. S., aged twenty. The upper arm had been almost amputated by an airplane propeller blade. The attending surgeon had conservatively débrided the wound, and had achieved an excellent reduction with a wire through the ulna for traction. However, follow-up roentgenograms revealed separation. Release of all traction failed to restore interfragmental contact, because of the extensiveness of the muscle severance.

On August 12, 1938, a manipulative attempt at reduction elsewhere and application of a cast left the fragments in the position illustrated.

FIG. 1-C FIG. 1-D

On July 22, 1939, by the simple expedient of placing half-pins above and below the fracture, then forcing the bone ends together and applying a short cast, firm bony union was obtained. Callus was very slow in appearing (about two months), because of the extensive arterial trauma. However, the humerus could be safely immobilized for a relatively long period, since the adjacent joints were left free for movement, and stiffness was avoided.

3. *Absorption of the Ends of the Fragments*

Bone, like any other living tissue, undergoes necrosis comparable to the degree of interruption of its blood supply. In many cases the amount of bone absorption is of no clinical importance because the fracture occurs in a highly vascularized, cancellous area, or in an oblique plane.

Absorption of the ends of the bone may not be evident for weeks or months. A perfect initial reduction may, at the end of the first or second month, reveal a space between the ends. Less than one sixteenth of an inch of space will delay union, which may even lead to a non-union. This is especially demonstrable in a severely traumatized transverse fracture in the distal third of the tibia, or in the mid-portion of the humeral shaft.

4. *Needless Operative Interference*

Just as the growth of grass depends on its water supply, so the rate of

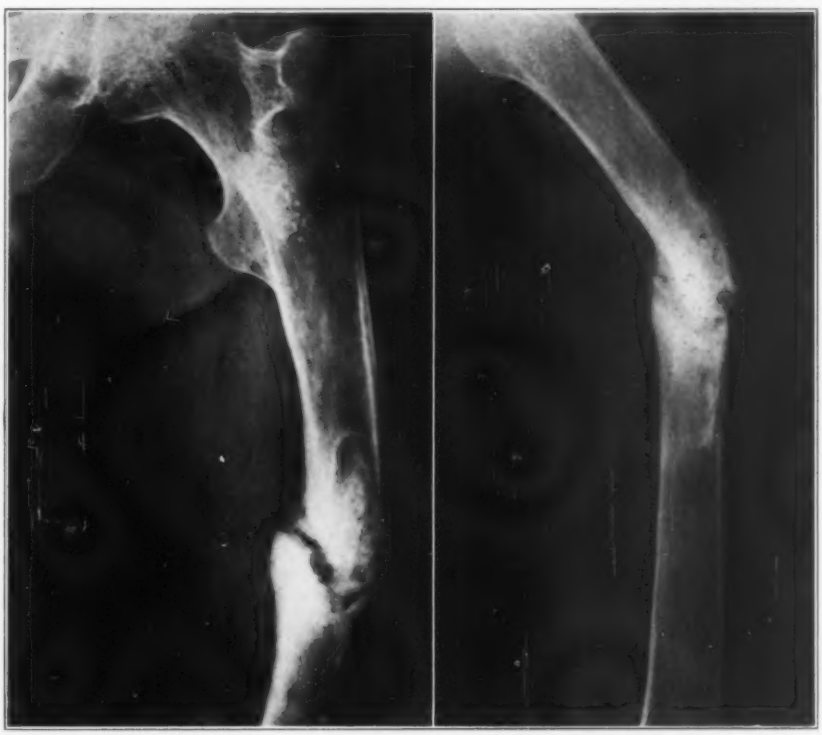

FIG. 2-A FIG. 2-B

Case 2. Mr. A. P., aged thirty-five, had a non-union of the shaft of the femur, resulting from an open reduction. This uncomplicated fracture in a healthy adult was plated eighteen hours after the accident. These roentgenograms were taken October 19, 1938, five years after the accident, following eight operations elsewhere. All operations except the last were free from infection. The local ischaemia and scarring incident to the original and subsequent operations are largely responsible for the persistent non-union. (In the authors' experience, almost all non-unions following simple fracture of the shaft of the femur occur in patients who have had open operations.)

On August 12, 1938, a manipulative attempt at reduction elsewhere and application of a cast left the fragments in the position illustrated.
relatively long period, since the fragments were free for movement, and stiffness was avoided.

formation of bony callus is directly dependent upon its blood supply. The fracture hematoma is an eloquent expression of the extent of the rupturing of the local blood supply. How can a fracture be exposed without further devitalizing the already traumatized periosteum and adjacent soft tissues? A firm plate across the fracture site, instead of holding the bones constantly in contact, will often actually hold them apart, because, as absorption of the bone ends takes place, the plate prevents contact. Of the patients first seen with non-unions of fractures of the femoral shaft, nearly all had previously been operated upon; those who had not been operated upon presented malunions.

B. NON-UNION FROM INADEQUATE IMMOBILIZATION

The principle of immobilization is nearly tantamount to that of reduction in the treatment of fractures. Inadequate fixation produces non-union as surely as does a failure to obtain apposition. Perfect immobilization implies a positive fixation of the fragments in end-to-end contact throughout the whole period of convalescence. Most of the present methods fall woefully short of this ideal.

1. *"Continuous" Traction*

Traction as commonly employed, with countertraction through gravity obtained by elevating the foot of the bed, is not a constant factor; it is ever changing. This is explained by the mechanical fact, not fully appreciated, that the amount of traction force exerted at the fracture site is in direct proportion to the amount of countertraction pull. Any change, such as lifting the patient for nursing care, increasing the height of the pillow, or using a trapeze, will affect the traction. Younger patients cause a separation of fragmental contact by pulling themselves upward. Furthermore, the initial traction necessary to effect a reduction will, as the muscles tire, later cause separation. Fluoroscopic examination during the nursing regimen will convince most skeptics of the activity in fragments so immobilized. Continuous traction, either adhesive or skeletal, cannot immobilize completely, because there is no direct attempt to control the superior fragment.

Constant irritation at the bone ends through insecure immobilization may precipitate a vicious circle, consisting of early local fibrosis and consequent interference with restoration of circulation. A similar phenomenon not infrequently follows open reduction.

2. *Plaster or Celluloid Casts*

Physiologically, it is impossible to immobilize completely fragments that are buried in the center of a soft mass of skin, fat, and muscle, without applying a cast so constricting that a slough will result. Recession of traumatic swelling, and the slow, insidious atrophy of soft tissues calls for a constant diminution in the diameter of the cast. A skin-tight cast, even if reapplied weekly, is not snug for more than a few days at a time.

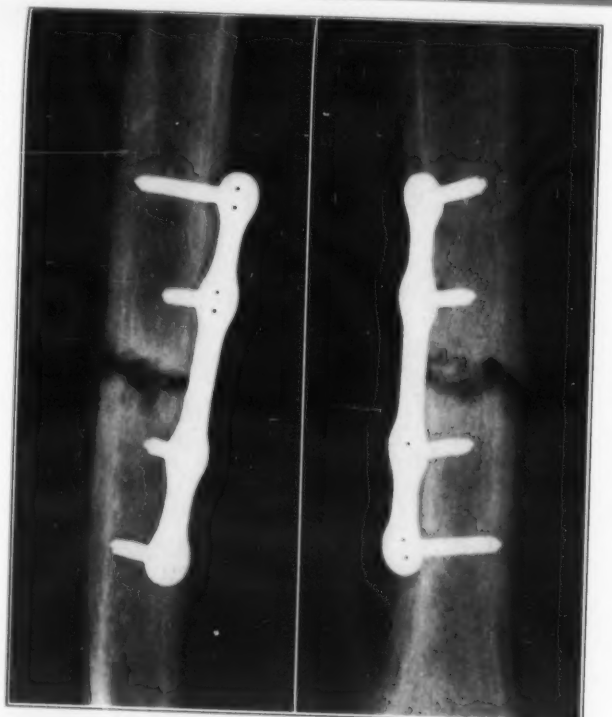

FIG. 3-A

FIG. 3-B

FIG. 3-C

FIG. 3-D

Case 3. Mr. P. R., aged twenty-nine, had a non-union of the shaft of the humerus with a lesion of the radial nerve. The patient was a logger, in excellent health.

Figs. 3-A and 3-B: These roentgenograms were taken September 30, 1936, when the authors first saw the patient, eight months after the plating. There was no postoperative infection, but the surgical trauma, added to the original injury, had further destroyed the blood supply sufficiently to produce late absorption of fractured ends. As this aseptic bone necrosis had taken place, contact between the bone ends had been lost, so that the plate actually held the bones apart, thus ensuring non-union. Inclusion of the radial nerve in the scar of the original compound wound, and prolonged convalescence had resulted in clubbing of the fingers and practically complete ankylosis of the fingers, wrist, elbow, and shoulder, with marked atrophy of the whole arm and hand.

Figs. 3-C and 3-D: February 4, 1939. End result following bone graft and neuroplasty. (At the time of the bone-graft operation, the nerve was found to be caught in both the surgical and compound wound scars. After it had been freed there was a gradual return of function.) By placing half-pins into each fragment, the fracture was completely immobilized by a short cast which extended only from the shoulder to the elbow, leaving both joints free for both active and passive movements. Surprisingly good function of the hand and other joints was obtained during the period the cast was on the humerus.

a. The spica used for fractures of the femoral shaft does not achieve positive fixation of the upper fragment, because the cast must be cut out over the sacrum and perineum, and the buttocks, big and flabby, change shape with the slightest shift in position. With atrophy of the soft tissues, the thigh muscles or gravity pulls the pelvis down into the thigh portion of the loose, funnel-shaped cast. Hip spicas thus fail to immobilize positively.

b. A shoulder spica can never be expected to fix positively a fracture of the shaft of the humerus, because of its anatomical relationship to other structures. The upper fragment is fixed to the thoracic cage by shoulder ligaments, muscles, and clavicle. Any movement of the thorax, such as a deep breath, an exerting movement of the opposite arm, or a sneeze, will directly cause movement between the fragments. This explains many of the non-unions of the mid-humeral shaft.

c. Hanging-cast therapy for fractures of the upper humerus, as advocated by Caldwell and others, will furnish brilliant results. However, this same technique should not be extended to transverse or extensively comminuted fractures of the mid-shaft, because, in a reclining position, gravity cannot act, and all fixation is lost. Furthermore, in this latter class of fractures, when the shoulder is exercised as advised, motion must take place at the fracture site, with a delaying if not lethal action on osseous repair. Are not dumb animals given pain perception to guarantee immobilization of a fractured leg?

d. In fractures of both bones of the leg, absolute fixation with a cast is impracticable, because of the tapering shape of the leg. Even a cast from the groin to the toes does not immobilize completely. Each time the cast is raised from the floor, in walking, the action of gravity on the long cast, resting chiefly on the dorsum of the foot, pulls the fragments apart, because the shifting soft tissues at the knee afford slight if any counterfixation. With failure to transfix each fragment, *early* weight-bearing on the cast thrusts the surfaces together. This action in the early stages of an untransfixed fracture can only cause injury to the fragile osteoblasts. Thus *early* ambulation in a cast without transfixions, which permits this to-and-fro squashing action, precipitates a fibrous type of repair at the fracture site,—a forerunner of non-union.

3. *Fixation by Open Operation*

At first thought, direct immobilization by internal fixation would solve the problem, but in many cases the internal fixation is inadequate to supply complete immobilization for a sufficiently long time. This is recognized by many, but not all surgeons. Often screws come loose, wires cut free, sutures absorb, and strong muscles recreate the deformity. While a plate, when first applied, holds the fragments of a transverse fracture in contact, later, after absorption has occurred, it just as securely holds the fragments apart. In addition, some of these fractures are actually plated with a space remaining between the fragments.

FIG. 4-A

FIG. 4-B

Case 4. Mr. W. K., a healthy, thirty-five-year-old male, had an operative non-union of the shaft of the radius.

The roentgenograms show the fracture on admission, ten months after an open reduction with subsequent extensive absorption of the bone ends. Failure of contact, inadequate immobilization, and surgical arterial trauma are a combination sure to produce non-union.

FIG. 4-C

FIG. 4-D

The roentgenograms show the end result eight months after bone grafting. The ulna was shortened to obtain radial contact, and the distal radial fragment and the superior ulna fragment were transfixed by half-pins in such a manner that the fingers could be immediately and consistently used without endangering the interfragmental contact.

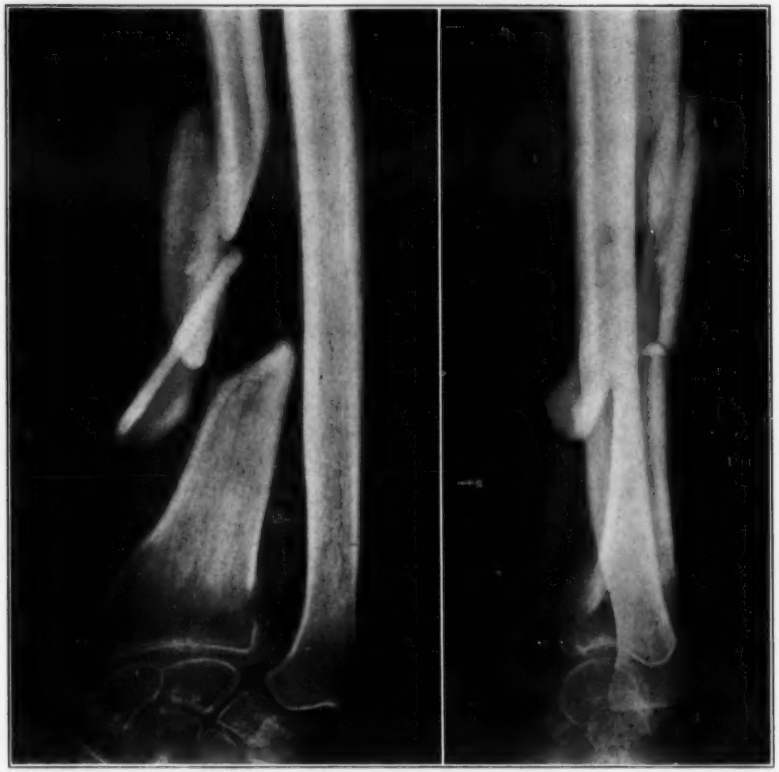

FIG. 5-A

FIG. 5-B

Case 5. Mr. J. W., a forty-year-old logging engineer, in excellent general health, had a non-union of the shaft of the radius, following closed reduction. March 21, 1939, ten months following injury. Prolonged immobilization without reduction had resulted not only in non-union, but also in a "freezing" of the fingers in extension.

FIG. 5-C

FIG. 5-D

Six and one-half months after operation, an excellent function had been obtained with a technique similar to that detailed under Figures 4-C and 4-D. The ulna should have been shortened to a greater extent.

of the fingers in extension.

FIG. 6-A

FIG. 6-B

FIG. 6-C

FIG. 6-D

Case 6. Mr. LaR., a young adult, aged twenty, in excellent general health, had a surgical non-union of the shaft of the tibia.

Figs. 6-A and 6-B: Roentgenograms were taken one year following plating of a fresh, uncomplicated fracture. The fibula progressed to early union. In the more poorly vascularized and surgically traumatized tibia, considerable bone absorption had taken place. As a result, both the plate and the fibula held the tibial bone ends apart,—an actual guarantee against union.

Figs. 6-C and 6-D: Result, after about four months, of a method allowing postoperative ambulation, which is described in legends for Figures 8-C and 8-D.

FIG. 7-A

FIG. 7-B

FIG. 7-C

Case 7. Mr. P. G., aged thirty-seven, had a non-union of the humerus as a result of returning to work without immobilization, before consolidation was complete. About five months later a beef-bone graft was inserted. This was followed by a discharge which lasted until the beef-bone graft was removed six months later. About two months after this, he had had another operation, which was followed by drainage.

Fig. 7-A: This roentgenogram was taken two and one-half years after the accident, when he came under the authors' care.

Fig. 7-B: A Henderson massive onlay graft was held in place with wood screws, and the fracture was immobilized with half-pins into the upper fragment.

Fig. 7-C: The end result two months after operation was firm bony union.

FIG. 8-A

FIG. 8-B

Case 8. Mr. J. W., aged thirty-two, had a non-union of the shaft of the tibia. He had been treated with a dual-transfixation technique. Judging from the history, excessive skeletal distraction during the first few weeks of healing discouraged normal bone repair. The transfixions had been removed at the end of the sixth week, and a cast, extending only to the upper calf, had been reapplied.

Roentgenograms were taken seven months after the accident.

FIG. 8-C

FIG. 8-D

October 31, 1939. Roentgenograms show the end result eight and one-half months after bone-grafting, at which time the distal fibula was obliquely osteotomized. Transfixation of each fragment and use of a walking cast permitted the patient to be completely clothed and ambulatory with crutches throughout the whole convalescent period. Such activity minimizes muscle and bone atrophy, increases local circulation, and results in earlier union without entailing the expense of the usual extended hospitalization. The psychic effect of painless ambulation in home environment is of inestimable value.

FIG. 9-A FIG. 9-B

Case 9. Mr. G. B., aged sixty-five, had non-union of both bones of the leg, caused by excessive skeletal distraction. Transfixions had been placed through the tibia above and the os calcis below the fracture site. The fracture was reduced, and the transfixions had been subsequently incorporated in a cast. From the history, an excessive and dangerous amount of traction used in the original reduction had been maintained by the transfixions. Interfragmental contact had been lost with the almost inevitable result of non-union. These roentgenograms portray the condition of the bones when the authors first saw the patient. Note the sequestrum in the os calcis, caused by sidewise movements of the os calcis on the wire.

4. *Fibular Distraction*

It is the authors' observation that a transverse fracture through the distal one-third of the shaft of the tibia, with the fibula intact, takes longer to unite than when both bones are broken at a similar level. Trauma to this already poorly vascularized area of the tibia results in absorption of the delayed type. As the intact fibula holds the fragments in their original position, the absorption of the ends results in a loss of contact, with a resulting delayed union or all too frequent non-union. In some cases, eventual union at the medial side of the fracture is achieved by permitting the tibia to shorten, thus assuming a position of varus at the ankle, but permanent varus weight-bearing is usually a real disability.

If there is an associated fracture of the fibula, the prognosis for early union is better. However, in not a few cases, the fibula solidifies at such a relatively early date that it henceforth acts as a tibial distractor, interfering with union. A prophylactic procedure in such cases may be used.

5. *Double-Pin Transfixation*

The injudicious use of double transfixation with overtraction is the surest way to obtain a non-union. Another danger of this technique in transverse fractures is that a late absorption of the bone ends not infrequently occurs, with a resulting loss of contact since the fragments are firmly fixed in the cast. This, if not corrected, favors non-union.

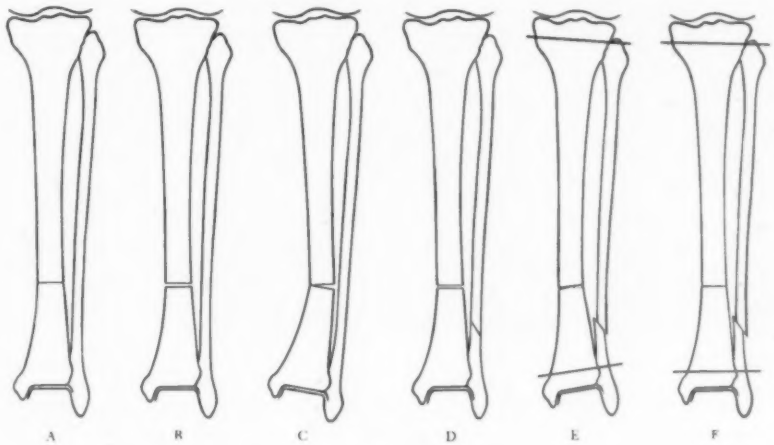

FIG. 10

An intact fibula (*A*) in fractures of the leg has long been considered a favorable factor, but the authors have found the opposite to be true because, as absorption occurs, the immobilizing fibula holds the ends of a transverse fracture of the tibia apart (*B*), resulting in delayed union or non-union. After absorption occurs, tibial contact can be obtained only by permitting lateral angulation (*C*), but approximation so achieved is at the expense of a permanent disabling varus deformity at the ankle.

In such transverse tibial fractures union can be obtained more assuredly and quickly by performing an immediate oblique osteotomy of the fibula (*D*).

Transfixions or half-pins are then placed through each tibial fragment (*E*), and the fracture is reduced and immobilized with the tibia in medial angulation and with some overriding of the fibular fragments.

After a few weeks' time, but before the fibular callus is completely ossified, a wedge-shaped section of the cast is removed over the fracture site, leaving a small segment over the lateral aspect as a hinge. If fixation rods have been employed, the same principles are followed. The alignment is then restored by swinging the foot medially (*F*). This action, which takes place with the green fibular callus as a pivoting center, forces the tibial ends into closer contact. The manoeuvre may need to be repeated, depending upon the rate of absorption. Finally, before the callus solidifies, it is of the utmost importance to see that the alignment of the ankle is at right angles or in slight valgus to the weight-bearing line.

C. PRESERVATION OF BLOOD SUPPLY

While it is axiomatic that callus formation is directly dependent on the blood supply, some fracture techniques utterly disregard this dictum. The use of a tourniquet or hemostat graphically demonstrates that surgical entrance can be obtained only by a sacrifice of the contiguous blood supply, and the exit closes by forming an inhospitable wall of fibrous scar.

Open reductions are still unsuccessful in a certain number of cases, because of lack of a skilled team or of operating dexterity, or because a

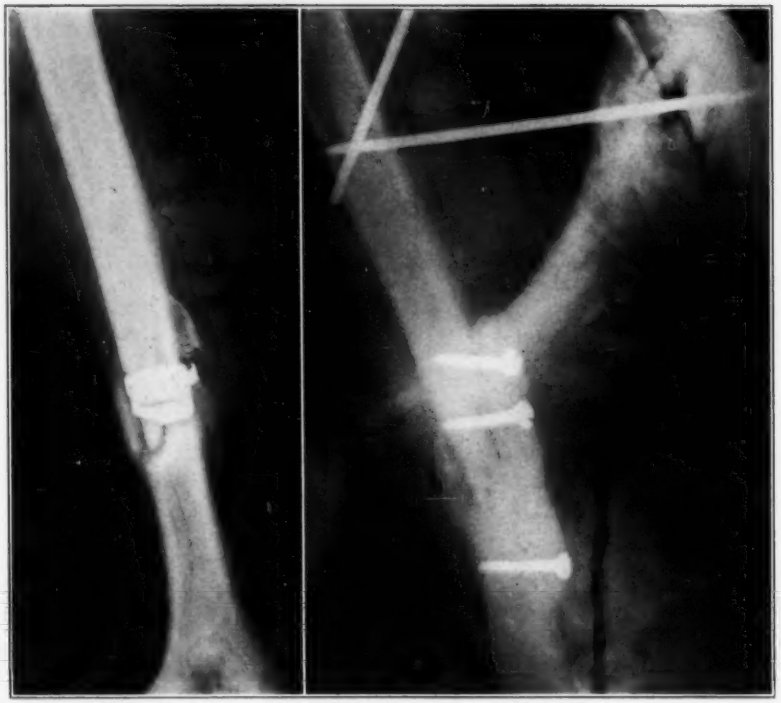

FIG. 11-A

FIG. 11-B

FIG. 11-C

FIG. 11-D

Case 10. Mrs. J. G. had a non-union of the humerus following an automobile accident. The patient was a very obese woman, thirty-nine years old, who had weighed over 300 pounds; her blood sugar had frequently passed the 275 level, with systolic blood pressure averaging around 85, so at first thought the cause of the non-union might be attributed to a polyglandular dyscrasia. However, a bony union was produced by immobilizing the humerus with half-pins following the placement of a bone graft, so the conclusion is evident that non-union had been due to a mechanical cause,—insecure fixation.

Fig. 11-A: February 7, 1939. Roentgenograms were taken five months after an operation which had been performed elsewhere. Bands not only had failed to secure fixation, but had acted as a deterrent to callus formation.

Fig. 11-B: May 11, 1939. Roentgenogram was taken through the cast, one and one-half months after operation. Note the extra length of the half-pins made necessary by a large mass of soft tissue to the lateral side of the humerus. There was no cast above the shoulder, so this joint was left free for immediate movement. Imagine the difficulties inherent in any attempt at immobilization by applying a spica to one so obese.

Figs. 11-C and 11-D: December 2, 1939. The end result of solid bony union was achieved chiefly through the application of the two principles,—reduction and fixation.

Figs. 11-C and 11-D: December 2, 1939. The end result of solid bony union was achieved chiefly through the application of the two principles,—reduction and fixation.

FIG. 12-A

FIG. 12-B

FIG. 12-C

Case 11. Mr. D. K., aged twenty, had a potential non-union of an extensive compound, comminuted, infected fracture, of the mid-shaft of the right femur. Excellent reduction had been obtained elsewhere by the well-leg method, but on removing the splint at the end of three months, the fracture fell apart. When first seen by the authors, there was still a discharge, but in spite of this, the transfixions were inserted in the routine manner, after which, the sequestra, as shown in Figure 12-A, were removed through a lateral incision; the wound was packed with Orr's vaseline gauze. To prevent any shortening in one so young, the transfixions were incorporated with the shaft in normal length with a large space between the ends of the fragments, as shown in Figures 12-B and 12-C.

The patient was very debilitated at the time of the insertion of the half-pins, but during convalescence he gained thirty pounds, which made a change of plaster necessary. The cast was removed after the thigh had been replaced in the anatomical splint. However, the transfixion wounds were not exposed or dressed at any time. Because of the inadvisability of fixation with direct contact of the fragments immobilization for more than six months was necessary.

break in the exacting technique may result in infection. The effects of such sepsis upon the blood supply and callus formation are too well known to require further elucidation. Why operate when reductions and positive fixation can be achieved without it? A meticulous and anatomical débridement in fresh compound fractures is a great aid; a ruthless and careless débridement is truly arterial murder.

Metabolic and Glandular Theories. The recent literature on the chemistry of vitamins, the synthesis of glandular products, the distribution of calcium, and the details of metabolism as related to callus formation has been so voluminous as to obscure free and analytical thought on the question of non-unions. To date the authors have yet to observe "faster" union through the use of any one of these forms of therapy.

PREVENTION

The formidable list of factors contributing to delayed or non-union may at first thought seem to be insurmountable. However, by closely following a technique which adheres to the three fundamental principles—reduction, immobilization, and preservation of blood supply—90 per cent. of delayed unions or non-unions can be entirely obviated.

Dual transfixation of both lower and upper fragments transforms the closed treatment of fractures from a haphazardous daily trial-and-error duty to a definite procedure that operates with mechanical certainty. Furthermore, for the first time, it not only standardizes fracture management, but also supplies an ambulatory system for the treatment of all shaft fractures. Outlined below are some of the major advantages inherent in the dual-transfixation technique which, when properly employed, most effectively lowers the incidence of delayed unions and non-unions.

FIG. 12-D

June 1935. During convalescence at home, the knee and hip joints were actively exercised, which overcame not only the pre-existing joint stiffness and muscle atrophy, but avoided circulatory stasis. Note the normal contour of the muscles of the calf and the absence of swelling at the ankle.

1. *Skeletal Countertraction.* Transfixation of the proximal fragment of a shaft fracture provides the most reliable form of countertraction; it is so controllable that fragmental contact throughout convalescence can be assured.

2. *Reduction Aid.* Transfixions through each fragment actually supply handles for direct manipulative reduction. No longer need the lower fragment be brought up into a gro-

tesque position in an attempt to approximate the loose, uncontrolled upper fragment. Accurate end-to-end reductions produce early unions.

3. *Unlocking Fractures.* When the fractured surfaces of an oblique or spiral fracture oppose rather than face each other, the fracture is considered to be locked. Dual transfixation of such fragments supplies control, so that the bone ends can be swung around each other into place before traction is applied. End-to-end reduction is thus accomplished by closed methods, and open operation with its surgical quota of non-unions is avoided.

FIG. 12-E FIG. 12-F

Roentgenograms show bony union. The compound wound has healed. The joints and muscles are normal and there is no loss of length.

4. *Adequate Immobilization.* Proximal and distal transfixions, when incorporated in a short cast or fastened to fixation rods, guarantee positive fixation. Reduction is continuously retained regardless of the movements of the patient. Such absolute and positive immobilization results in earlier union.

5. *Controlled Contact.* It has been pointed out that circulatory injury from the original trauma, especially in transverse, comminuted, or compound fractures, may result later in enough absorption of the bone ends to be of clinical danger. With the method of dual transfixation, this loss of contact can be quickly remedied by removing a thin, circular section of the cast over the fracture site and compressing the fragments together, or by adjusting the fixation rods so as to re-establish bony contact. The danger of skeletal traction as ordinarily employed is overtraction, but in this method the process is reversed, for the transfixions are now used to force the fragments together into constant "contact". The benefits of such a technique are particularly applicable to the difficult transverse fractures of the shaft in areas heretofore so often the site of non-union.

6. *Physiological Benefits of Ambulation.* With transfixation of each fragment, only the broken bone is immobilized, leaving the contiguous joints free for immediate use. This movement not only prevents joint stiffness, and muscle and bone atrophy, but increases the circulation gen-

erated by muscle contraction. The deleterious action of a stagnant venous flow is nicely portrayed in the formation of chronic varicose ulcers. Persistent swelling, phlebitis, and thrombophlebitis, so often seen in immobilized extremities, can be largely avoided when muscle activity is permitted.

Extended elevation of an extremity with muscle inactivity will result in vascular atresia as surely as it does in muscle atrophy. This vascular insufficiency is later frequently expressed in the form of oedema of the ankle. On the other hand, when the patient is ambulatory and active, normal contraction of the muscles calls for an increased arterial income, and at the same time the contracting muscles press on the veins, accelerating the venous flow. Since formation of callus is directly dependent on the blood stream, it is evident that active muscle contraction will speed the union and prevent vascular atresia.

Confinement of the patient to bed lowers all activities, while ambulation calls for general and local muscle work. This exercise "normalizes" the circulation, increases the metabolism, and assists elimination. Psychic stimulus from ambulation and home surroundings, even though of indirect relationship, undoubtedly benefits the rate of fracture repair.

All of the patients of whom illustrations are shown were healthy young males, except the patient in Case 10, and ranged in age from twenty to forty years, with the exception of the patient in Case 9, who was sixty-five years old. Age, therefore, can be eliminated as an etiological factor. The fractures were surgically exposed in every case, except in Case 1, but the presence of infection prevented bone-grafting in Cases 2, 9, and 11. Every patient was immobilized by the double-pin or half-pin "controlled contaction" method. Solid bony union has been obtained in all cases, with better joint and muscle function following the removal of fixation than was present when treatment was initiated, with the exception of Case 2. This patient demanded release from treatment. The authors did not blame him for tiring of further treatment, in view of his five years of unsuccessful surgical treatment. Nevertheless, they felt that union probably could have been obtained if treatment had been continued.

Immobilization by double transfixation supplementing operation for non-union provides many outstanding advantages, the first of which is such firm immobilization that the minimum of local fixation is called for; in addition, this technique furnishes means for immediate ambulation on crutches. Further, external means of fixation is minimal so that the adjacent joints may be moved both actively and passively from the first, thus preventing ankylosis, muscle atrophy, and vascular atresia. The many physiological, economic, and psychic advantages of a convalescence at home are appreciated by the patient and his family as well as by the attending surgeon.

SUMMARY

Delayed unions and non-unions in fractures of the shaft of long bones are by a very large majority man-made, as an analysis reveals that the

attending surgeon in such cases has failed to observe the basic principles of fracture treatment. The various ways in which the three fracture commandments are daily being broken both by conservative skeletal traction and by operative methods have been described. When the *A*, *B*, *C's* of fracture therapy (*A*, reduction; *B*, immobilization; and *C*, preservation of blood supply) are employed, over 90 per cent. of slow unions are circumvented.

Prevention of non-unions can be achieved by a simple and practical fracture system which calls for direct skeletal control over *both* proximal and distal fragments. With the use of the dual-transfixation technique, the care of fractures of the extremities is simplified, standardized, and made available to all surgeons, regardless of location, who either by preference or necessity are faced with fracture problems.

FRACTURE OF A BIPARTITE CARPAL NAVICULAR

Report of a Case

BY H. M. CHILDRESS, M.D., CHARLESTON, SOUTH CAROLINA

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Bipartite carpal naviculars are not often encountered, and a fracture of such a bone must be classed as a rarity. This case is being reported, not only because of the coincidence, but also because it illustrates well the value of checking unusual bone findings in an extremity with roentgenograms of the opposite normal one.

J. M. E. About one week before the patient, a white male, aged twenty-nine, was examined, he had fallen upon ice, and had sustained a severe trauma to the right wrist. All motions of this joint had remained limited and painful. The patient stated that ten years previously, while practicing football, he had injured the wrist in much the same manner, and that roentgenograms made several months later had shown a fracture of the right carpal navicular. He had obtained relief by wearing a circular plaster casing for three months. However, he has had frequent similar injuries to the right wrist since then, and has always felt a weakness and insecurity in this joint.

Physical examination revealed marked tenderness to pressure over the right carpal navicular. Tapping upon the flexed proximal interphalangeal joints of the right index and middle fingers, with the metacarpophalangeal joints extended, also produced pain in the navicular area. All wrist motions, except adduction, were limited about 50 per cent. Adduction was extremely painful, and was limited about 75 per cent.

Roentgenograms of the right wrist were made in four positions. One view (Fig. 1) was interpreted as an old fracture of the carpal navicular with traumatic arthritis between the fragments. Also, the distal portion appeared to be rotated 90 degrees clockwise. Because of these unusual findings, a roentgenogram was taken of the patient's left wrist, and the left navicular was found to be bipartite. The original roentgenograms taken in 1931 were obtained, and they showed the right navicular to be bipartite, and its distal fragment to be fractured (Fig. 2). The abnormal appearance of the distal portion, therefore, was due to malunion, and not to rotation as was first believed. Excision of the smaller fragment was advised, but refused. A molded leather wrist cuff was applied, which partially relieved the discomfort.

Dwight [1] has stated that in a bipartite navicular, the line of division runs obliquely from near the outer end of the articular surface of the radius to about the middle of the concavity of the head of the capitate. The accuracy of this observation may be noted in the roentgenograms of this case.

When unusual roentgenographic findings of the carpal navicular are observed, it is important to consider developmental variations.

1. Dwight, Thomas: A Clinical Atlas. Variations of the Bones of the Hands and Feet. Philadelphia, J. B. Lippincott and Co., 1907.

FIG. 1

Roentgenogram taken at time of recent injury was interpreted as an old fracture of the carpal navicular with traumatic arthritis between the fragments and rotation of the distal portion.

FIG. 2

Original roentgenogram, taken in 1931 several months after the first injury, shows the right navicular to be bipartite with its distal fragment fractured.

RECURRENT DISLOCATION OF THE ULNA AT THE ELBOW

BY JOSEPH A. GOSMAN, M.D., RACINE, WISCONSIN

From St. Luke's Hospital, Racine

Milch [1] in 1936 reported a case of bilateral recurrent dislocation of the ulna at the elbow, and described its treatment by the use of a bone block. In the intervening time, the author has not seen a report of any similar case. The following is an example of a recurrent dislocation of the congenital type, treated in the same manner.

J. S., a female, aged fifteen, appeared at St. Luke's Hospital, May 23, 1941. The patient had fallen when she was three years of age, and since then had had recurrent dislocations at the left elbow,—four of them recently. Slight jars to the extended arm had been the usual cause. There had been no fractures associated with the dislocations, and up to this time she had been able to reduce the dislocations without medical aid. On admission, the patient displayed an arm with the typical characteristics of posterior dislocation at the elbow. This was confirmed by fluoroscopy. Reduction was performed under gas anaesthesia, and a roentgenogram was taken to rule out chip fractures (Fig. 1). There was very little swelling at this time and recovery was rapid, so that at the end of a week there was complete return of function without pain.

It was noted that the range of motion at both elbows was in excess of the normal. With full flexion bilaterally, the volar surface of the forearm and wrist completely touched the upper arm, traversing an arc of at least 165 degrees; extension was possible to 10 to 15 degrees past 180 degrees. She was hypermobile in most joints of the upper and lower extremities.

On July 30, 1941, the condition recurred, and on August 13, 1941, the operation, essentially as described by Milch, was carried out. A small tibial peg was placed in a drill hole in the coronoid process and was impacted (Fig. 2). The postoperative course was uneventful. The patient was discharged from the Hospital on August 17, 1941, and the cast was removed on August 26, 1941. Daily treatments with heat and massage were given for six weeks, and motion was rapidly regained. At the end of one year, flexion was possible to 135 degrees. At this point, the patient felt the end of the bone peg press into the coronoid fossa. Extension was equal bilaterally to 10 to 15 degrees past 180 degrees. With vigorous use there had been no recurrence. Figure 3 shows the elbow one year after the operation.

The author's only variation from Milch's operation was in the shape of the peg. Milch chose one of boomerang shape to form a continuous line with the curve of the coronoid process. The author, however, used a rectangular peg because of its simplicity, and because it was certain to be remodeled along more symmetrical lines during the process of absorption of the bone of the graft, and the substitution of new bone.

Milch's case apparently was due to an insufficiently prominent coronoid process and a relatively shallow semilunar notch. In the one here reported, the bones appeared to be normal, but the ligamentous binding of the joint appeared to be flaccid, probably on a congenital basis, thus permitting dislocation in hyperextension.

1. MILCH, HENRY: Bilateral Recurrent Dislocation of the Ulna at the Elbow. J. Bone and Joint Surg., XVIII, 777, 1936.

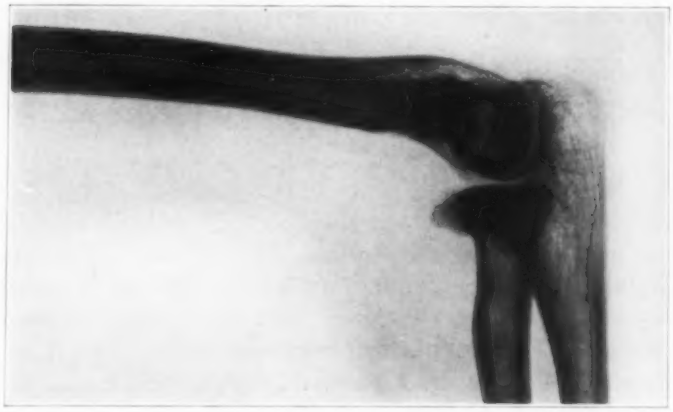

FIG. 3

August 20, 1942. Some absorption of the peg and removal of sharp corners has taken place.

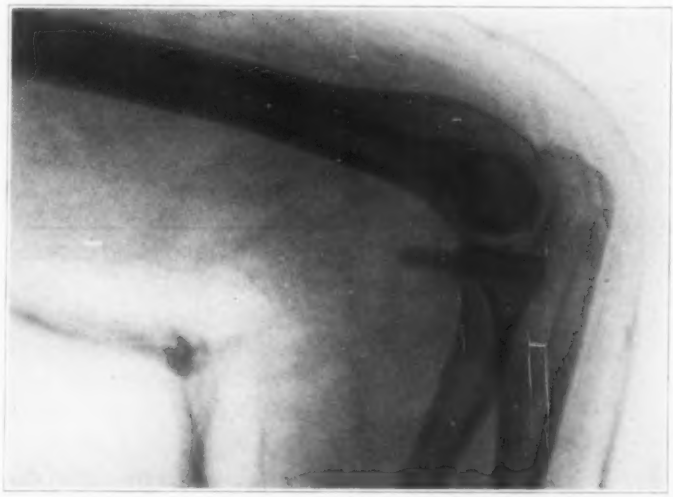

FIG. 2

Left elbow in cast postoperatively, showing peg in the coronoid process.

FIG. 1

May 23, 1941. Preoperative view of left elbow. The bone structure is apparently normal.

A METHOD OF FEMUR TRACTION WITH FOOT REST

BY ERNEST H. BETTMANN, M.D., WHITE PLAINS, NEW YORK

From the Blythedale Hospital for Crippled Children, Valhalla, New York

Orthopaedic conditions sometimes require a method of traction which is easy to apply and remove,—for instance, in cases where traction has to be maintained for a long period of time, but has to be removed periodically for physiotherapy or exercise. In searching for a method of traction for the lower extremity which would avoid the difficulties inherent in either skeletal or skin traction—joint stiffness and knee instability (81 per cent. of the author's former cases treated by adhesive traction), skin irritation, and shortening of tendons—the condyle region of the femur was found to be a safe working point to offer painless traction for the hip joint. The cone-shaped region of the distal femur with the crest of the condyle laterally, the upper patellar margin anteriorly, and the popliteal fossa posteriorly, forms a triangle on which an even pressure and pull find safe anchorage, without involving distal joints (Fig. 1).

FIG. 1

Traction cuff anchored to the femoral condyle.

The author's method of traction offers the following advantages: It exerts a steady pull above the knee joint by a circular grip which is automatically tightened when traction is increased. The foot is placed comfortably in an adjustable foot rest, thus preventing faulty position and deformities. The apparatus can be applied and removed immediately in patients of any age, who require traction of the hip or femur. This is of special value in cases where traction over a long period is interrupted by physiotherapy, as in Legg-Perthes disease or hip contractures (Figs. 2 and 3).

The construction of the apparatus for traction of the

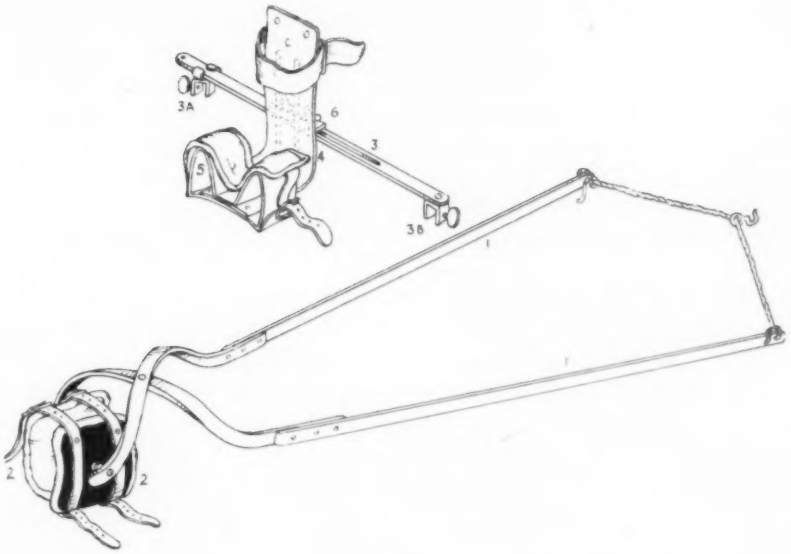

FIG. 2
Ice-tong device with separate foot rest.

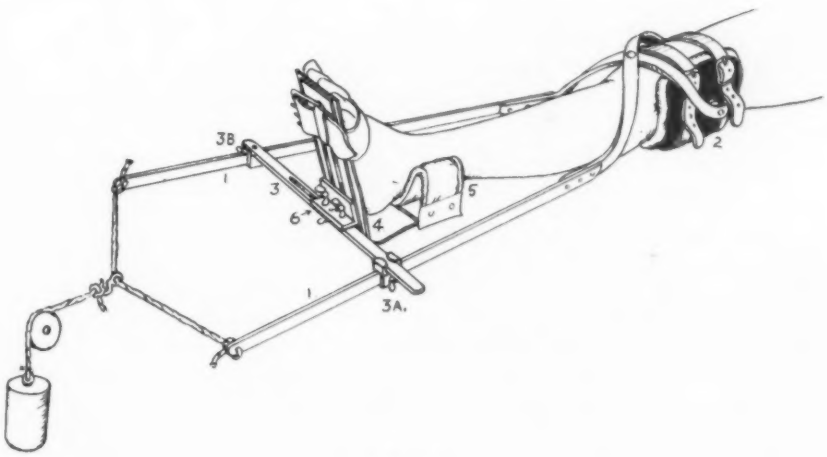

FIG. 3
Traction has been adjusted.

femur is as follows: Two duraluminum bars twenty inches long (*1*), crossing six inches below the proximal end to form an ice-tong device, are fitted with two padded aluminum pads (*2*). These pads, connected by two pairs of straps which buckle to them, fit closely to the distal end of the femur, and, being shaped in a semicircular base, form a tight condylar rest. A cord connecting the distal arms brings them together more with increasing weight pull, and thus causes a proportional tightening of the pads. This is followed by adjustment of the foot rest, consisting of

a cross bar (*3*) which glides at right angles to the traction pull and is adjustable on the traction arms by means of screw devices with pivots (*3A* and *3B*). A sole piece (*4*), allowing horizontal and up-and-down motion on the bridge by means of three screws which glide in slots (*6*), guarantees proper foot position. An adjustable leather band (*5*) supports the calf.

This automatic "ice-tong" method has been used for nine months for the following conditions:

Legg-Perthes disease	15 cases
Coxitis with flexion contracture	3 cases
Spastic paraplegia with drop-foot	2 cases
Low-back pain with arthritic changes or sciatic syndrome	8 cases
Involvement of the hip in Gaucher's disease	2 cases

The apparatus has been applied with traction, varying in amount from six to fifteen pounds, for periods ranging from three days to four months, during which time the traction has been kept on constantly, or has been removed daily or weekly for additional therapy or examination. The majority of the patients were children between five and sixteen years of age, except the group of adults with low-back pain.

DISSEMINATED (MILIARY) TUBERCULOSIS OF BONE WITH MULTIPLE LOCALIZATIONS IN THE SKELETON

A Report of Two Proved Cases

BY JOHN LYFORD, III, M.D., BALTIMORE, MARYLAND

From the Division of Orthopaedic Surgery, The Johns Hopkins Hospital, Baltimore

Reports of proved tuberculous lesions occurring in multiple bones are not common. Examples of the simultaneous involvement of multiple bones, in which the lesions were proved to be tuberculous by finding *mycobacterium tuberculosis* in stained smears of material from the bone lesions, by animal inoculations, or by both procedures, have been cited by Carrell and Childress, Hodges, Schwenkter, Stalmann, Van Alstyne and Gowen, and Kelley and Sailer. These last described tuberculous lesions in numerous bones in a young colored man. In their case it was of note that the Mantoux test was positive at only a low dilution of old tuberculin, the urine was positive for Bence-Jones protein, and at autopsy there were found associated tuberculous lymphadenitis, pericarditis, and miliary involvement of the viscera.

In this report two cases are described of proved disseminated (miliary) tuberculosis of bone with multiple localizations in the skeleton, because of the interesting clinical pictures and diagnostic problems they present.

Case 1. A. C. N., a white man, thirty-two years old, entered the Johns Hopkins Hospital October 28, 1941. He had been treated elsewhere for a persistent low-back pain since August, 1939, when he had fallen and severely hurt his lower spine. A dull lumbosacral pain had persisted despite the use of a back brace; and after five months a fusion of the third, fourth, and fifth lumbar vertebrae had been performed with a graft from the left ilium, followed by immobilization of the spine for three months. The pain had persisted unabated, and, ten months after the onset, it had begun to radiate to the now tender left iliac crest and down the anterior aspect of the left thigh into the lower leg and ankle. Four months later both knees and the left ankle had swelled; there had been local heat; and clear straw-colored fluid had been aspirated from the knee joints. During the twenty-one months following the spine fusion, the patient had received sulfathiazole, roentgenotherapy, artificial fever, injections of neoarsphenamine and bismuth, and a long course of potassium iodide,—all without relief of his symptoms. During the seventeen months previous to admission, the patient's temperature had varied between 100 and 105 degrees daily with the peak occurring at irregular intervals. Four months before admission, an appendectomy had been performed for abdominal pain, and a normal appendix had been found. The patient had never had any known exposure to tuberculosis.

Physical examination on admission: Temperature was 100 degrees; pulse, 110; respiration, 22; blood pressure, 100/60; weight, 131 pounds; and height, seventy-four and one-half inches. The patient appeared drawn and haggard with poor color. He stood with a prominence of the spinous process of the third lumbar vertebra and a slight posterior bowing of the entire lumbar spine. Motion of the spine was limited in all directions, but there was very little spasm of the paravertebral muscles. Flexion of the right hip was limited moderately, and very slight shortening of the right tensor fascia lata existed. There was tenderness over the right tibia, left shoulder, and vertebral border of the left scapula.

The laboratory findings are summarized in Table I.

Roentgenograms revealed extensive destructive changes in the third and fifth lumbar vertebrae, several ribs, the wings of the ilia, the left ischium, the left scapula, the right humerus, and the upper end of the right femur. The most characteristic of these are shown in Figures 1-A, 1-B, and 1-C. The bones of the hands, feet, and skull showed no lesions, and the lungs were clear.

The patient's course in the Hospital was marked by a spiking temperature varying between 99 and 101 to 102 degrees daily, with no fixed hour for the peak. On the ninth hospital day, a biopsy of the lesion in the left ilium was performed, and a gelatinous material was found, surrounded by a well-demarcated wall of fibrous tissue. Acid-fast bacilli were found in stained smears of this material, and were grown in cultures of the material; and the guinea-pig test was positive for tuberculosis. The operative incision healed *per primam* without any drainage or sinuses ever developing. Three weeks later, in an attempt to desensitize the patient, he was given two subcutaneous injections of a tuberculin broth filtrate: one of 1:1,000,000 dilution, and after three days another of 1:100,000 dilution. The injections were discontinued because the patient's temperature rose to increasingly higher peaks, and the differential white-blood-cell count showed 89 per cent. neutrophilic cells. After six weeks the patient left the Hospital, with his temperature still ranging daily between 99 and 101 degrees, to return home on a regimen of bed rest, and calcium and vitamin-D therapy. Nothing further concerning his status has been learned.

FIG. 1-A

Case 1. Anteroposterior view of the pelvis showing the multiple lesions in the ilia, ischium, and fifth lumbar vertebra. (Illustration reversed.)

FIG. 1-C

Anteroposterior view of the left scapula showing the areas of destruction. (Illustration reversed.)

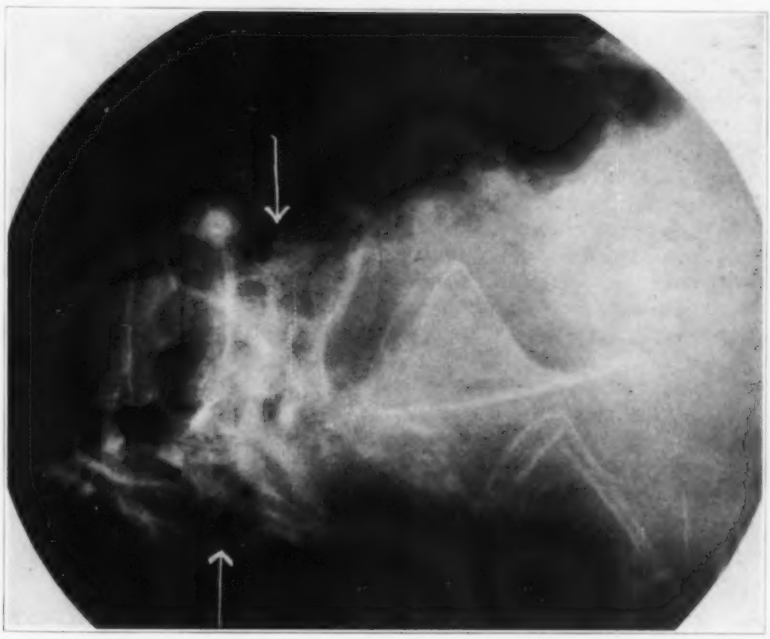

FIG. 1-B

Lateral view of the lumbosacral region showing the spinal fusion and the lesions in the body of the fifth lumbar vertebra.

CASE 2. G. R., a colored male coal miner, thirty-four years old, was first admitted to the Johns Hopkins Hospital September 24, 1941, with the history of having been struck on the back eighteen months before. Immediately following the trauma, he had had moderate pain in the lumbar region, which had persisted and had prevented him working since that time. Ten months before admission, abscesses had developed over

TABLE I

LABORATORY FINDINGS

	Case 1	Case 2
Red-blood-cell count	4,440,000 per cu. mm.	4,580,000 per cu. mm.
Hemoglobin	11.5 grams (80 per cent.)	12.5 grams (85 per cent.)
White-blood-cell count	11,800 per cu. mm.	6,450 per cu. mm.
Volume packed red blood cells	38 c.c. per 100 c.c.	36 c.c. per 100 c.c.
Sedimentation rate:		
1 hour	30 mm.	53 mm.
corrected	27 mm.	32 mm.
Icteric index	4	5
Mean corpuscular volume	86 cubic microns	79 cubic microns
Mean corpuscular hemoglobin	26 micromicrograms	27 micromicrograms
Mean corpuscular hemoglobin concentration	36 per cent.	35 per cent.
Blood non-protein nitrogen	28 mgm. per 100 c.c.	25 mgm. per 100 c.c.
Fasting blood sugar	91 mgm. per 100 c.c.	
Blood cholesterol	165 mgm. per 100 c.c.	
Blood calcium	9.9. mgm. per 100 c.c.	
Blood phosphorus	3.7 mgm. per 100 c.c.	
Phosphatase activity	3.2 Bodansky units	
Total serum protein	6.52 grams per 100 c.c.	
Serum albumin	4.04 grams per 100 c.c.	
Albumin-globulin ratio	62/38	
Urine:		
Sulkowitch test	Negative	
Bence-Jones protein	Negative	
Blood serum agglutination test for brucella	Negative in all dilutions	
Stool guaiac test	Negative	
P.S.P. kidney excretion test:		
dye excreted at 15 minutes	50 per cent.	
dye excreted at 30 minutes	15 per cent.	
dye excreted at 1 hour	10 per cent.	
dye excreted at 2 hours	10 per cent.	
dye excreted total	85 per cent.	
Old tuberculin skin test:		
1:100,000	Negative	Positive
1:10,000	Negative	
1:1,000	Positive	
Blood flocculation test for syphilis	Negative	Negative
Blood Kline test for syphilis	Negative	Negative
Blood chloride		97.4 milliequivalents per liter
Carbon dioxide combining power of blood plasma		48.5 vols. per 100 c.c.

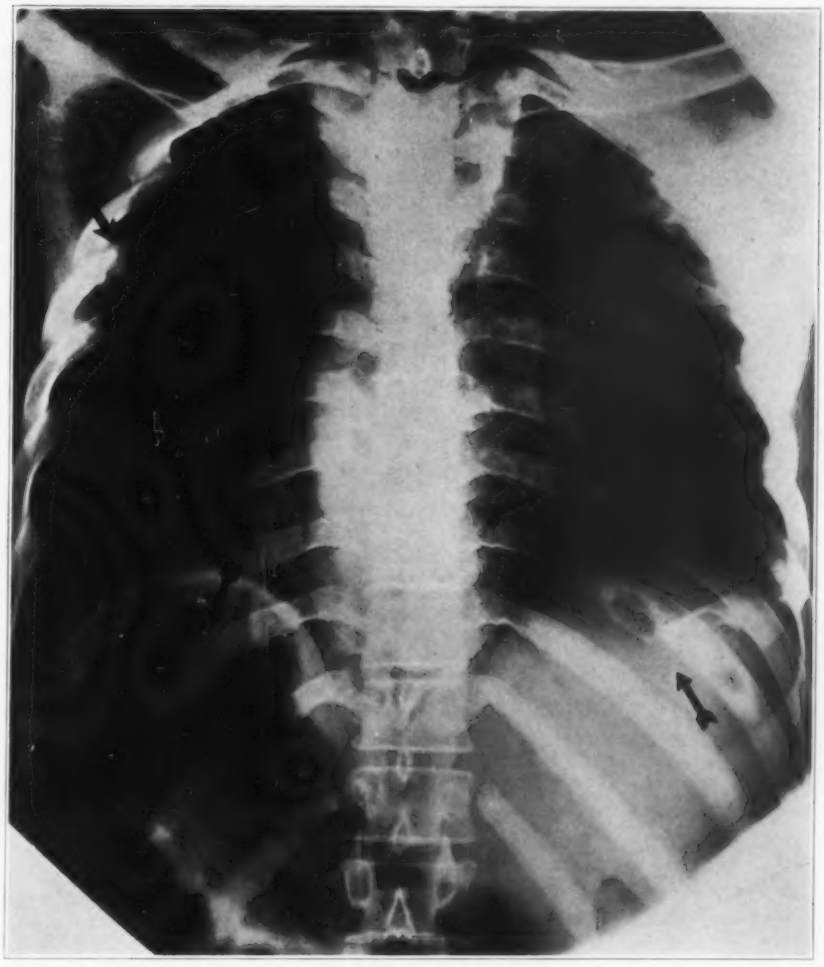

FIG. 2-A

Case 2. Roentgenogram of the thorax showing the multiple lesions in the ribs.

his back and sternum. These had been incised, and permanently draining sinuses had formed. For eight months before admission, any motion of the neck had caused cervical pain, and there had been a persistent lump in the left cervical region. The patient had never had any known exposure to tuberculosis.

Physical examination on admission: Temperature 98.8 degrees; pulse, 104; respiration, 20; blood pressure, 136/92; weight, 118 pounds; and height, sixty-five and one-half inches. The patient appeared undernourished and chronically ill. There was a cold, fluctuant mass, measuring about four by two centimeters, in the left posterior cervical region behind the sternomastoid muscle, and another over the right second costochondral junction. There were two draining sinuses in the left lumbar region, and one posterior to the right shoulder. Rotation of the neck was markedly limited by pain.

The laboratory findings are summarized in Table I. No fungi could be grown in cultures of material from the sinuses or sternal mass. Acid-fast bacilli were demonstrated in cultures of material from the cervical mass, and hemolytic *staphylococcus aureus* was grown in cultures of material from a sinus of the back.

Roentgenograms showed the lungs to be clear. There were multiple expanding and destructive lesions of several ribs, vertebrae, bones of the shoulder girdle, and pelvis. The lesions in the pubis and left ilium seemed to be much older than those in the other bones, and only that in the ilium appeared sclerotic. No lesions were seen in the long bones. The more characteristic roentgenograms are shown in Figures 2-A, 2-B, and 2-C.

Course. The patient was hospitalized for seven days in September 1941, and during that time he had a daily temperature between 97 and 101 degrees, spiking in character and with the peaks at irregular times of the day. A biopsy of a rib was performed, and the lesion was seen to be a moth-eaten area from which thick, yellow, purulent material escaped. Examination of the material removed from the rib revealed caseous tubercles, and acid-fast bacilli were demonstrated in stained smears. The patient left the Hospital to return home on a regimen of bed rest.

December 4, 1941, the patient was readmitted to the Hospital for six days. The physical findings were essentially the same as before, but there were now eight draining sinuses about the trunk. Again the patient had a daily irregular spiking temperature between 99 and 102 degrees. A plaster collar was applied to relieve the persistent cervical pain, and the patient returned home to remain at rest on a diet rich in calcium and vitamins. Nothing further has been learned concerning his status.

In these cases certain facts are of interest. In both instances acid-fast bacilli were demonstrated in the bone lesions; the lungs were clear; no

FIG. 2-B

Anteroposterior view of the pelvis showing the multiple lesions in the ilia and pubes.

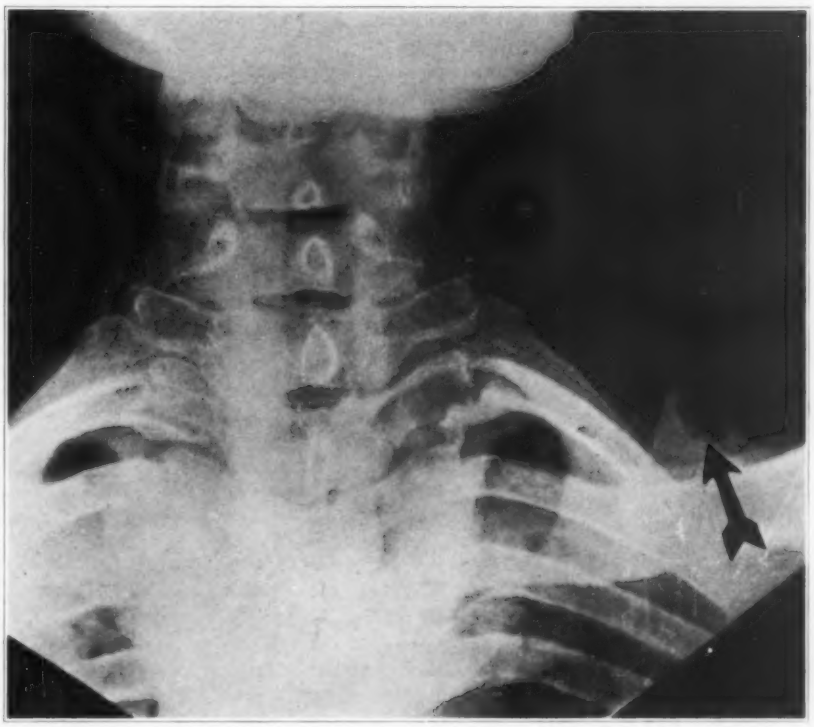

FIG. 2-C

Anteroposterior view of the right scapula showing the destructive lesion in the scapula. (Illustration reversed.)

joints were involved; the clinical course of the disease was more or less chronic, and was introduced by trauma; and there was a persistent daily spiking temperature with irregular peaks. Both patients were young adult males. In one case the bone lesions were sclerosing in character and no sinuses ever formed; in the other the lesions were of the caseous type and associated with multiple abscesses and draining sinuses. The variation in the strength of the old tuberculin necessary for positive skin reactions in the two patients illustrates again that with bone tuberculosis this reaction varies with the ability of the individual to react to the infecting organisms. The absence of any lesions in the bones of the hands or feet separates these cases from the group of osteitis tuberculosa multiplex cystica as described by Jüngling. The problems of differential diagnosis in these cases are readily apparent. It is evident not only that tuberculosis should be considered in all instances of multiple bone lesions in which the cause is obscure, but that this diagnosis should be confirmed by demonstration of the tubercle bacilli in the lesions.

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EPIPHYSEAL DYSPLASIA PUNCTATA IN A MOTHER AND IDENTICAL MALE TWINS

BY EBER RESNICK, M.D., LOS ANGELES, CALIFORNIA

From the Children's Hospital, Los Angeles *

A review of the literature reveals only scattered case reports of this unusual condition. Most authors are convinced that the epiphyseal dysgenesis is connected with a hypothyroid condition, though several case reports manifesting these changes give laboratory results which indicate that the thyroid functioning was normal.

At the Children's Hospital of Los Angeles, a mother and her two identical male twins have been followed from birth to puberty, all three individuals showing roentgenographic evidence of epiphyseal stippling. A brief summary of the three cases follows:

CASE 1. Mother, aged forty-two, was born of Italian parents. She had had a normal delivery, and had had no serious illnesses during early childhood. At the age of six, she began to complain of pain and limp in both hips, and was brought to this Hospital, where a diagnosis of multiple osteochondritis was made from the roentgenograms. She was treated symptomatically, and gradually, after puberty was reached, her hip pain disappeared. Since that time she has had recurrent attacks of pain, never severe enough to incapacitate her. Unfortunately, her early roentgenograms were destroyed, but recent ones showed the following conditions:

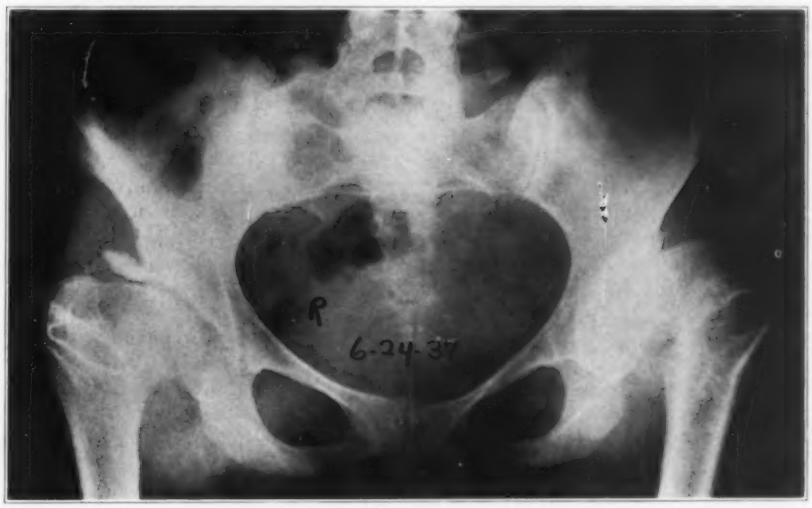

FIG. 1-A

Case 1. June 24, 1937. Mother's pelvis shows flattening of both femoral heads, foreshortening of both femoral necks, upward displacement of femoral shafts, and an unusually broad pelvis.

* Service of John C. Wilson, M.D.

Hands

Foreshortening of the metacarpals,
Broadening of terminal distal portions of the metacarpals,
Cupping of the interphalangeal joints;

Pelvis

Flattening of both femoral heads,
Foreshortening of both femoral necks,
Upward displacement of the femoral shafts,
An unusually broad pelvis.

Shoulders

Humeral heads show evidence of early chondritis by their abnormal shape.

The author has no evidence that this patient had a hypothyroid condition, since her development had progressed normally from a clinical standpoint.

In October 1927, identical male twins were delivered at full term, by caesarean section. Each child weighed over five pounds at birth, and the mother gave no history of having had previous miscarriages or abortions.

A summary of the case records of each boy follows:

Case 2 (Twin 1). On December 11, 1928, at the age of thirteen months, Twin 1 was admitted for circumcision. Examination revealed no abnormalities; no teeth were present at this time.

On November 22, 1930, tonsillectomy and adenoidectomy were performed, and on January 27, 1931, a right inguinal hernioplasty.

On July 14, 1937, at the age of nine years and eight months, the patient was admitted for pain in the left hip. It was intermittent and of moderate severity. The old-tuberculin test was negative. Roentgenograms of the hip at this time were reported negative. The child was put in traction to relieve the muscle spasm which was rather marked.

On October 26, 1937, roentgenograms of the left hip showed increased widening and irregularity of the left capital femoral epiphyseal line. There was no change in the femoral head. On April 28, 1938, the roentgenogram of the left hip showed aseptic necrosis of the medial pole of the left capital epiphysis, and the joint space to be somewhat widened. The basal metabolic rate on July 1, 1937, was minus thirty-one, and the patient was given one-half grain of thyroid daily. Blood cholesterol was 137 milligrams per 100 cubic centimeters. Creatinine and creatin-excretion tests gave the following results: Creatinine, 0.49 milligram per cubic centimeter, or 609.8 milligrams in twenty-four hours; creatin 0.164 milligram per cubic centimeter, or 203.6 milligrams in twenty-four hours. The patient was sent to a convalescent home where his left hip was kept in traction for seven months. Pain disappeared, and recent roentgenograms showed a completely regenerated left capital epiphysis. The thyroid medication was irregular because the patient did not tolerate it well. At the present time this boy is a normal fourteen-year-old male, with no symptoms of hip disease. He is doing well in school.

Case 3 (Twin 2). On December 11, 1928, Twin 2 was circumcised at the age of thirteen months. No abnormalities were noted; no teeth were present.

On September 2, 1930, a right indirect inguinal hernioplasty was performed, and on November 22, 1930, a tonsillectomy and adenoidectomy.

On March 13, 1933, the child was admitted, at the age of six years, with a history of pain in the right hip of one year's duration. It was of moderate severity, was present at all times, and radiated to the knee. The pain had become progressively worse. The old-tuberculin test was negative. Muscle spasm and limitation of motion were present. Roentgenograms were negative at this time, and diagnosis was deferred. In August 1932, roentgenograms showed changes in the right femoral capital epiphysis. Progressive roentgenograms from this time on showed what was felt to be a fairly typical course

of Perthes' disease, with flattening of the epiphysis, increased density, and fragmentation, with terminal regeneration resulting in a deformed right femoral head and neck. This child also was confined to bed with traction to the right hip for seven months. The basal metabolic rate was minus thirty, and blood cholesterol was 137 milligrams per 100 cubic centimeters. Creatinine and creatin-excretion tests gave the following results: Creatinine, 0.473 milligram per cubic centimeter, or 419.5 milligrams in twenty-four hours. Creatin 0.209 milligram per cubic centimeter, or 185.3 milligrams in twenty-four hours. At the present time, this child is a normal male who is active in all respects mentally and physically, and who does well at school. However, he has moderate pain on active use of the right hip.

FIG. 1-B

Case 1. Mother's hand shows foreshortening of the metacarpals, broadening of the terminal distal portions of the metacarpals, and cupping of the interphalangeal joints.

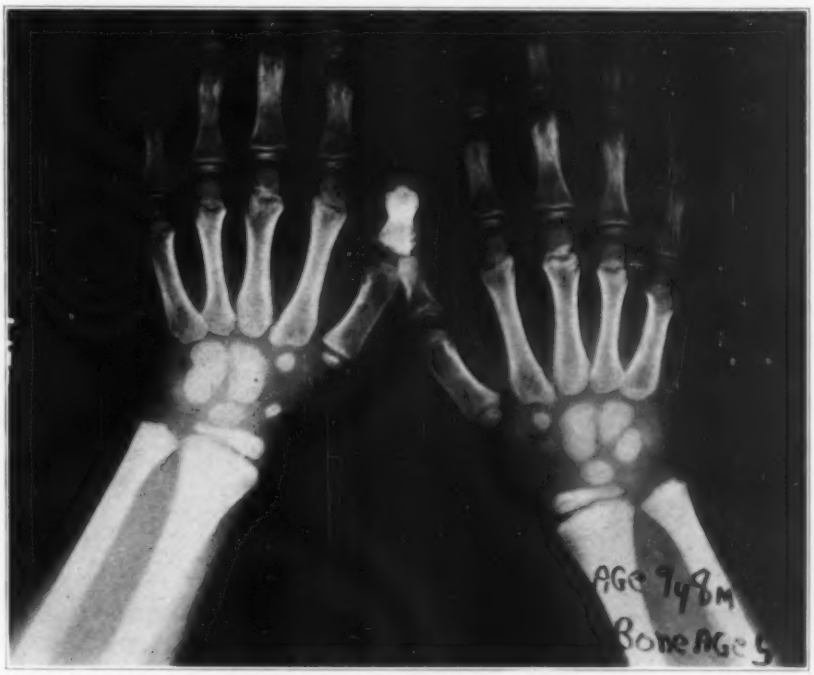

FIG. 2-A

Case 2 (Twin 1). June 22, 1937. Roentgenogram shows delay in the appearance of the carpal bones, as well as trumpeting of the metacarpal heads, and cupping of the interphalangeal joints.

FIG. 2-B

Case 2 (Twin 1). April 28, 1938. Roentgenogram of pelvis shows aseptic necrosis of the medial pole of the left capital epiphysis, and a somewhat widened joint space.

FIG. 2-C

Case 2 (Twin 1). February 21, 1941. Roentgenogram shows complete regeneration of the left capital femoral epiphysis.

FIG. 3-A

Case 3 (Twin 2). August 11, 1932. Roentgenogram shows narrowing of the right capital epiphysis.

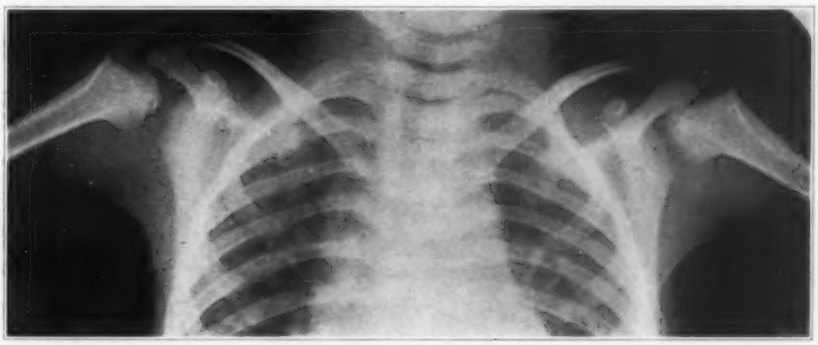

FIG. 3-B

Case 3 (Twin 2). March 22, 1933. Roentgenogram shows stippling of both humeral capital epiphyses.

Routine roentgenograms of the skeletal systems of both boys showed gross underdevelopment of all bony epiphyses, a delay of about five years in bone age as compared with the chronological age. The humeral heads showed stippling, the interphalangeal joints showed cupping and trumpeting, and the epiphyses of the long bones showed some evidence of irregular calcification. The epiphyseal lines were also irregular.

The only symptoms the three members of this family had were those of hip disease, and there was no laboratory or clinical evidence of hypo-

FIG. 3-C

Case 3 (Twin 2). June 21, 1937. Roentgenogram shows further progression of the disease with deformity.

FIG. 3-D

Case 3 (Twin 2). September 5, 1941. The right femoral head is deformed, with early closure of the epiphyseal line.

FIG. 3-E

Case 3 (Twin 2). June 26, 1937. Roentgenogram shows delayed appearance of carpal bones as well as a minor degree of trumpeting of the metacarpal heads, and cupping of the interphalangeal joints.

thyroid disease except for the basal metabolic rate, but this test is not too reliable in children, and the clinical trial of thyroid medication was unsuccessful because the drug was poorly tolerated; irritability and weight loss were noticed in a short period of time. The blood cholesterol levels in both children—137 milligrams per 100 cubic centimeters—was in the low-normal range. There is good evidence that patients with hypothyroid conditions have diminished excretion or even suppression of excretion of creatin, and these two patients had practically normal results.

Punctate stippling of the epiphyses is apparently associated with hypothyroidism in many cases, and is manifested in the roentgenogram by the appearance of multiple loci of calcification which coalesce to form an irregular, porous mass. This condition may be grouped with the chondrodystrophies, and it may be related to certain endocrine dysfunction, but apparently it is not always associated with congenital hypothyroidism, and thus should not be given the name "cretinoid epiphyseal dysgenesis".

SUMMARY

An Italian mother and identical male twins showed roentgenographic evidence of multiple osteochondritis with underdevelopment of the epi-

physes, not associated with a definite hypothyroid state. No symptoms were associated with the osteochondritis except those of the hip joints. At the present writing, the mother has deformed femoral heads and necks which cause pain and limp. The one child whose epiphyseal changes left him with a deformed femoral head and neck also has moderate pain on active use, while the other child, whose left upper femoral capital epiphysis regenerated so that normal contour resulted, is symptom free.

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AN INEXPENSIVE PORTABLE FRACTURE TABLE

BY FIRST LIEUTENANT HOWARD DUDGEON, JR., WACO, TEXAS
Medical Corps, United States Army
AND FIRST LIEUTENANT BERNARD J. RIKE,* PUEBLO, COLORADO
From the 174th Station Hospital

Many small hospitals, especially Army medical installations, are not equipped with an adequate fracture table, either because of the prohibitive cost or the inability to obtain such equipment at the present time because of the shortage of strategic materials and the difficulty of transportation in the zone of operations.

Although the majority of fractures may be adequately treated with the equipment at hand, fractures of the shaft of the femur necessitate the application of a hip spica, and this type of cast cannot be applied satisfactorily without special equipment. For these reasons, it was necessary to improvise a fracture table which could be quickly and easily constructed from available materials, and easily dismantled for transportation. It was also essential that the construction be sufficiently simple so that neither highly skilled mechanics nor special machinery was necessary.

The table here described may be added to the equipment of small mobile hospitals and hospitals without a standard fracture table, without jeopardizing the essential mobility of the unit or adding greatly to the cost of equipment. The authors feel that the small added cost and bulk of such a table is more

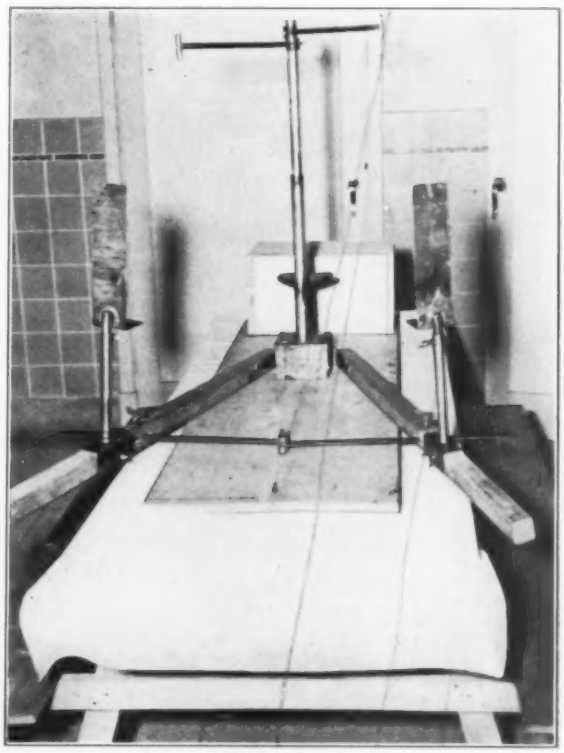

FIG. 1
End view of the table assembled for use.

* Died in the Southwest Pacific area January 5, 1943.

STOCK LIST

Amount	Item No.	Description
1	1	3 feet of 1-inch iron pipe, outside diameter
1	2	1 foot 9½ inches of 1⅜-inch iron pipe, 1 inch inside diameter
1	3	10 inches of 1½-inch iron pipe, 1⅜ inches inside diameter
1	4	2 feet of ¾-inch steel rod
1	5	3 feet of ½-inch steel rod
1	6	4 inches of 5/16-inch steel rod
1	7	9 inches by 10 inches of ⅛-inch sheet steel
1	8	1 foot by 3 feet of 3/32-inch sheet steel
1	9	4 feet of ⅛-inch strap iron
6	10	¼-inch nut
2	11	¼-inch winged nut
4	12	¼-inch by ½-inch winged bolt
2	13	¼-inch by 1½-inch winged bolt
2	14	¼-inch by ¾-inch bolt
4	15	⅜-inch by 4¾-inch carriage bolt
1	16	¼-inch by 2½-inch carriage bolt
20	17	No. 14, 1-inch wood screws
18	18	No. 9, 2-inch wood screws
14	19	⅜-inch washers
1	20	6 feet of 1-inch by 3-inch lumber
1	21	10 feet of 2-inch by 2-inch lumber
1	22	6 inches of 6-inch by 6-inch hard wood timber
1	23	12 square feet of ¾-inch ply wood
2	24	7-inch hinge.

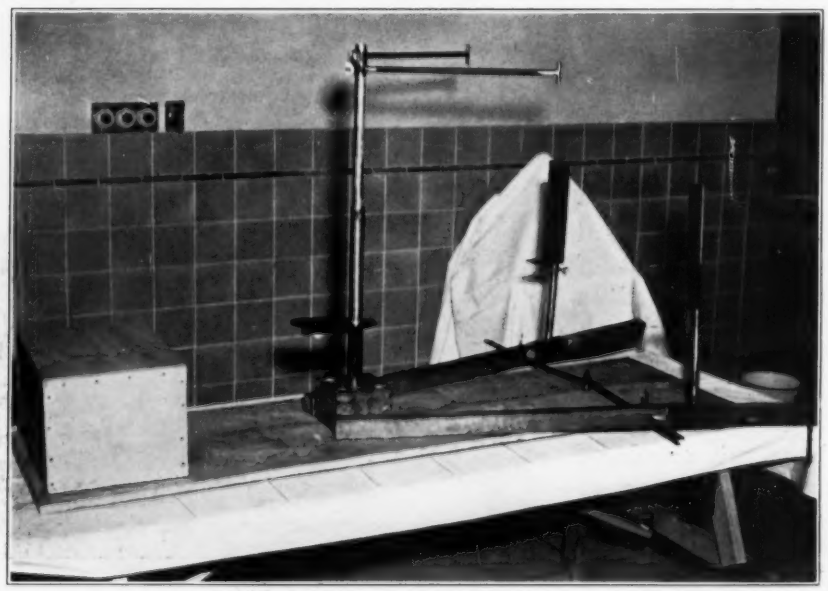

FIG. 2

Side view of the assembled table.

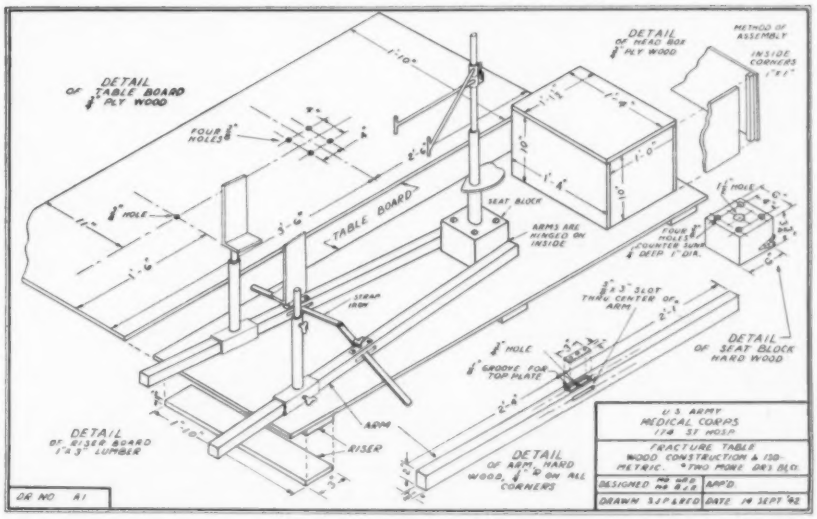

FIG. 3-A

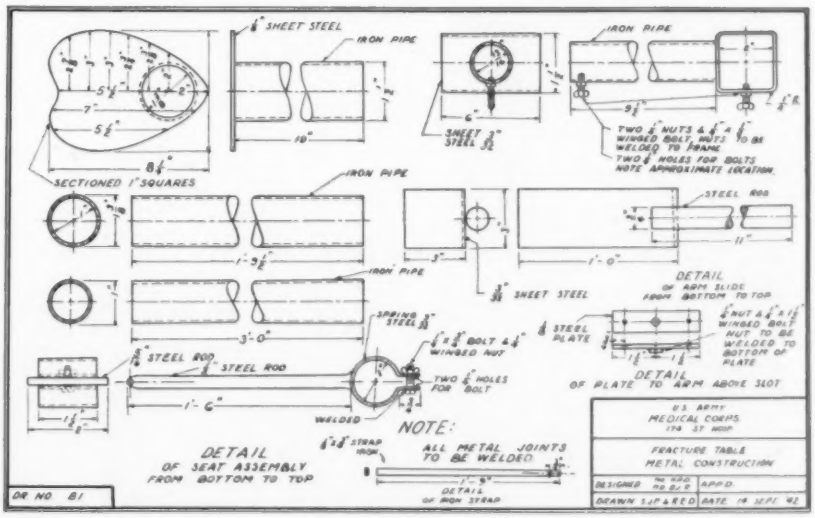

FIG. 3-B

Details of the construction of the table.

than justified by the greatly increased medical attention which may be given to patients with fracture of the femur without immediately transferring them to Base Hospitals. It is also felt that this table will solve the problem of the small civilian hospital which cannot afford a standard commercial table.

The approximate cost of the table, including labor and materials, would not exceed twenty-five dollars, and in many instances would be even less. Crated for shipment, it will not exceed 100 pounds in weight.

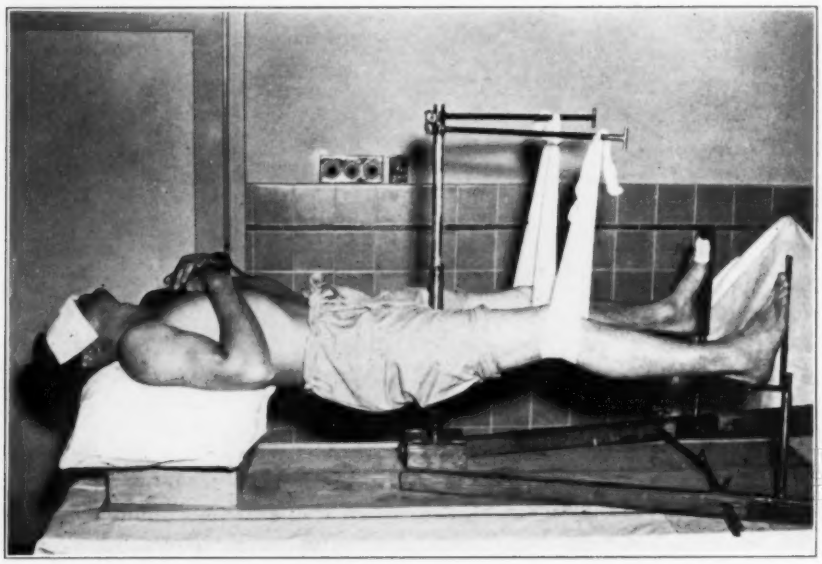

FIG. 4

View of table with patient suspended for the application of plaster.

The accompanying illustrations demonstrate the simplicity of construction and use of the table (Figs. 1, 2, 3-A, 3-B, and 4).

A SPLINT FOR CERVICAL FRACTURES AND DISLOCATIONS

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The transportation of patients with fractured and dislocated necks has always been a problem, but never more so than in time of war. This splint was devised primarily to simplify and ensure the safe transportation of such patients. It combines the principles of traction, extension, and immobilization. It can easily be applied in the field, and has a wide

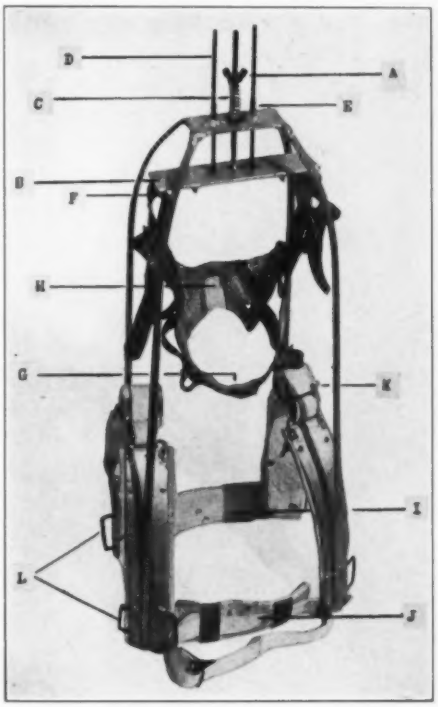

FIG. 1

FIG. 2

FIG. 1: The splint with head sling in place. Traction is applied by the wing nut (*A*) which, when tightened, raises the movable crossplate (*B*). Sudden jars are cushioned by the spring (*C*) and rotation is prevented by the lateral riders (*D*) which run freely through the top plate in welded tubular sleeves (*E*). The head sling is attached to the movable crossplate, the straps running through steel loops (*F*). It resembles the Sayre head sling, but has completely adjustable chin (*G*) and occiput (*H*) straps. The shoulder pieces are united posteriorly as a yoke by a padded steel crosspiece (*I*), and are made more adjustable by the chest strap (*J*) and the shoulder straps (*K*). Axillary straps can be passed through the loops (*L*) to secure the splint more firmly.

FIG. 2: This view shows the splint in place with the subject *in the supine position*. Traction has been applied and the neck has been immobilized in slight extension. More extension may be obtained by adjusting the head sling.

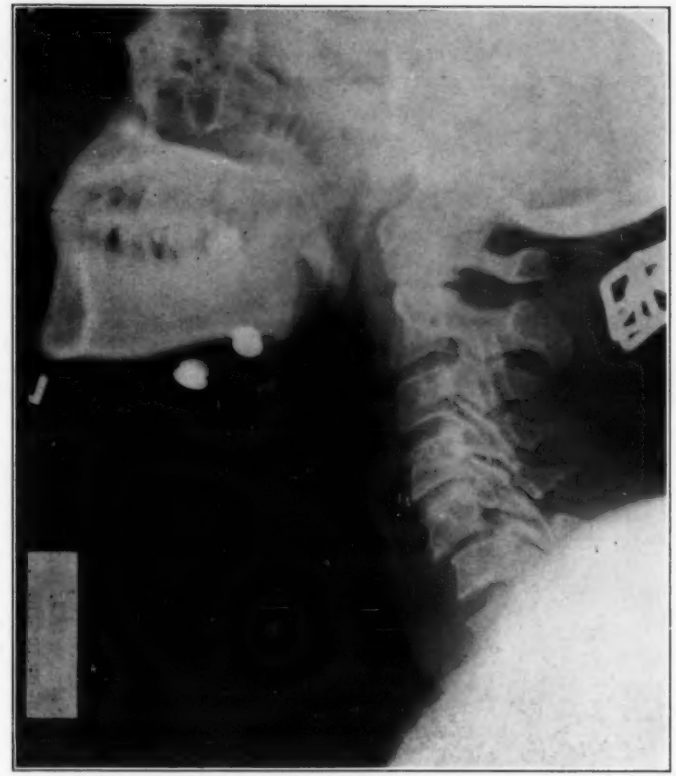

FIG. 3-A

Roentgenogram taken after twenty-four hours of traction with pulley and eight-pound weight, showing the overriding of the fifth cervical vertebra on the sixth.

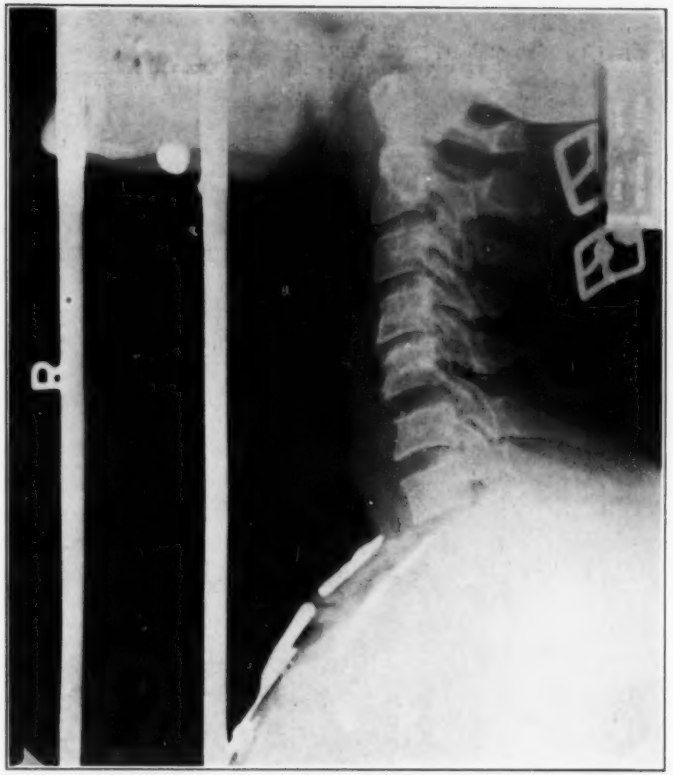

FIG. 3-B

Roentgenogram taken twelve hours after application of the cervical splint with forty pounds of traction. Note the widened intervertebral spaces due to the traction as compared with that in Fig. 3-A and Fig. 3-C. Note also the visualization of the seventh cervical not seen in the plates taken with less traction.

margin of adjustability as to size and the amount of traction and extension. The firm immobilization not only simplifies transportation, but, also, nursing care in the hospital, because the patient can be rolled over in bed and moved from stretcher to the X-ray table, with the possibility of further trauma minimized.

FIG. 3-C

Roentgenogram taken immediately after that illustrated in Fig. 3-B. The traction has been released to twelve pounds, enough to hold the position gained.

The splint consists of a quadripod, rising from a shoulder yoke from which the countertraction is exerted. This frame is slipped under the patient in the supine position, and the head sling is applied without any unnecessary movement of the neck. Traction is regulated by a wing nut, and a spring takes up sudden jars during transportation. The amount of traction can be easily measured by hooking an ordinary fisherman's scales under the movable cross plate, and tensing it until the opposing tractions are equal.

The construction of the splint permits unobstructed anteroposterior and lateral roentgenograms to be taken. The countertraction pushing down on the shoulders simplifies visualization of the seventh cervical vertebra.

Although the splint was primarily designed for the transportation of patients with fractured or dislocated necks, it has been used for treatment in one case.

A barge captain, fifty-five years of age, was brought in with a fracture-dislocation of the fifth on the sixth cervical vertebra with a complete paralysis from the level of the first thoracic vertebra down. He had been lying for twenty-four hours unattended, before he was brought to the Hospital. After twenty-four hours of regular traction with an eight-pound weight over a pulley, only slight reduction was gained. The splint was then applied with forty pounds of traction. The accompanying roentgenograms were taken

before, and twelve hours following its application. Although reduction was obtained, the neurological signs did not change, probably due to pre-existing trauma to the spinal cord. Further observations could not be made, because the patient died four days later of lobar pneumonia. Reduction no doubt resulted from the increased traction applied.

No definite conclusions can be drawn concerning the therapeutic value of the splint from this one case, although its use here proved efficacious mainly because it simplified nursing care and minimized the possibility of any change in the amount of traction or in the position of the patient's neck when he was moved about in bed.

The advice of William Darrach, M.D., Alan deForest Smith, M.D., and John Scarf, M.D., and the help of Mr. Frank Dowd, of the Hospital Work Shop, in its construction are deeply appreciated.

MIGRATION OF A KIRSCHNER WIRE FROM THE SHOULDER REGION INTO THE LUNG

Report of Two Cases

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The surgical repair of injuries in the past two decades has been marked by a trend toward the introduction into the tissues of divers types of metal plates, pins, wires, screws, and cups. There is an increasing tendency on the part of surgeons to discover new uses for these metallic aids. This has been particularly noticeable since Sherman's popularization of stainless steel, the experiments of Venable and Stuck with vitallium, and, more recently, the acceptance of tantalum and 18-8 SMO steel as almost inert substances.

The author has successfully treated several fractures of the clavicle by introducing Kirschner wires through the medulla of this bone, according to the technique of Gordon Murray. When a patient with a separation of the acromioclavicular joint was admitted some months ago, the author fixed this joint by passing wires across it. This procedure resulted happily, inasmuch as the repair of the rupture of the joint was successful, but unfortunately the wires, instead of remaining where they were so carefully placed, migrated in various directions. Subsequently one was removed from beneath the deltoid, the other from the right lung. The case report follows:

A twenty-seven-year-old sergeant in the United States Marine Corps was admitted to the United States Naval Hospital on April 21, 1941, two hours after falling and striking the right shoulder. He thought the shoulder was dislocated; pain was noted on certain motions; and there was a constant dull ache. Physical examination and routine laboratory work-up were negative except for the local condition. The right shoulder presented prominence of the outer end of the clavicle. There was pain on abduction of the shoulder above 70 degrees. A definite separation of the right acromioclavicular joint, readily reducible, was present.

Two days after admission a blind wiring of the joint was done. Reduction was firm, and one week later the patient had a full range of painless motion. However, inasmuch as the reduction was incomplete and the patient was conscious of its incompleteness, he desired anatomical reduction. The tip of the wire protruded into the deltoid, and it was decided to insert the wire under direct vision.

This was done on May 3, 1941, through a hockey-stick incision, and two Kirschner wires were inserted (Fig. 1-A).

An uneventful convalescence followed. Six days after operation the patient could extend the arm to a vertical position. On the twentieth day, he was discharged to light duty with a full range of painless motion. On June 20, 1941, he returned for follow-up. He had no complaint; the reduction was firm; and roentgenograms showed beginning calcification of the ligaments (Fig. 1-B). One of the wires at this time had

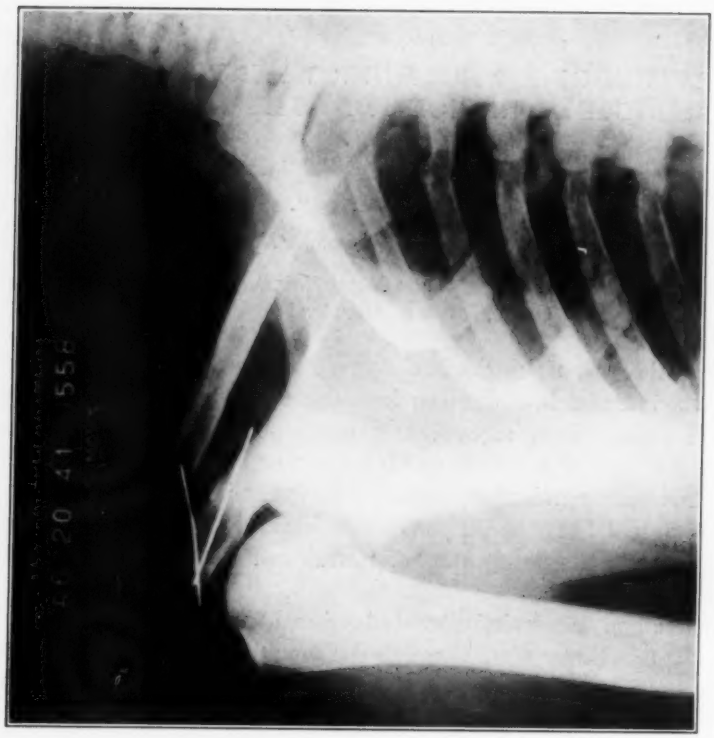

FIG. 1-B

June 20, 1941. Seven weeks after the second operation, there is beginning calcification of the coracoclavicular ligament, and one wire is out of the clavicle.

FIG. 1-A

Case 1. May 3, 1941. Roentgenogram following second wiring shows two wires traversing the joint, and firmly maintaining reduction.

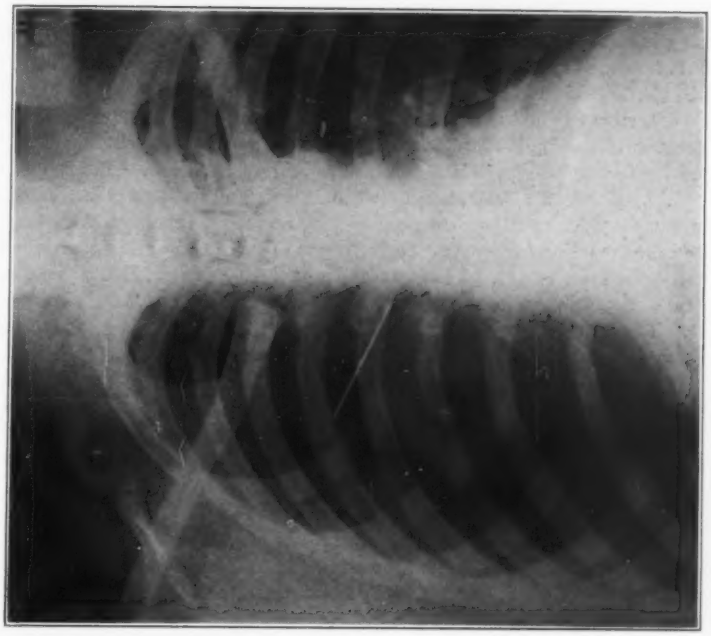

FIG. 1-D

August 11, 1941. There is partial collapse of the right lung, and a change in the position of the remaining wire.

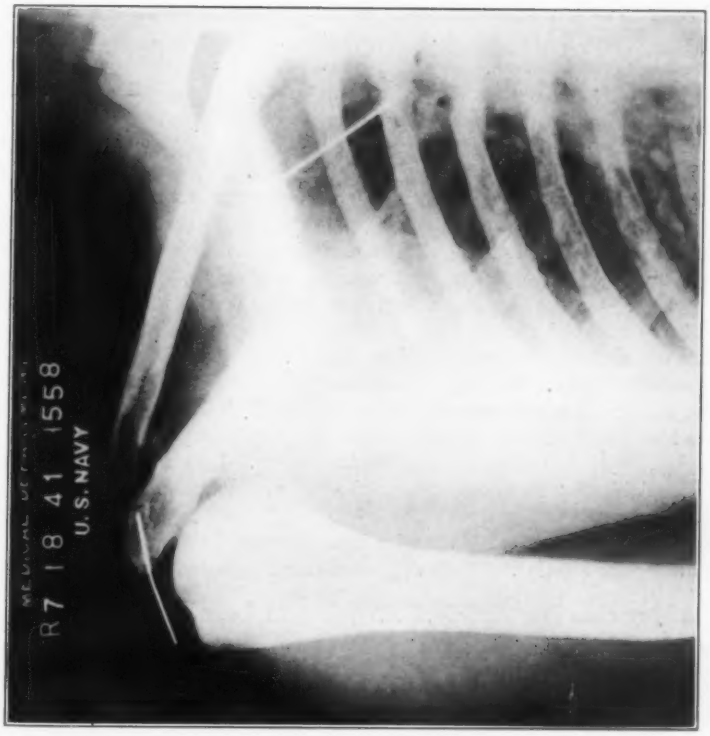

FIG. 1-C

July 18, 1941. Eleven weeks after the wiring, one wire is backing out through the deltoid, and the other is in the right lung. The ligament is well calcified.

worked out of the clavicle, but remained in the acromium. On July 18, 1941, he stated that he was doing full duty, carrying a rifle on the injured shoulder without discomfort, but that he could feel one of the wires protruding into the shoulder muscles. This was palpable beneath the deltoid and slightly tender. It was removed. Roentgenograms of this date (Fig. 1-C), showed good calcification of the ligament, but caused considerable perturbation because the second wire appeared to be lodged in the right lung. The patient returned for further study, which confirmed the apprehension. The report of C. F. Behrens, M.D., on July 22, 1941, stated, "Fluoroscopic and radiographic studies of the chest and right shoulder reveal a fragment of wire about six centimeters in length (originally placed on the acromioclavicular region) now to be in the right upper lobe of the lung toward the posterior aspect. The inner end is at the level of the fifth rib near the chondro-vertebral articulation; the opposite end is at the level of the third rib's mid-posterior aspect. The slant of the fragment is downward and medially. The lung tissue shows no evidence of reaction. The second fragment of wire originally placed in the acromioclavicular region is no longer seen." [It had been removed.] The patient's only complaint relating to the wire in the chest was an occasional twinge of pain beneath the scapula. There had been no cough, hemoptysis, sweats, or respiratory difficulty. However, the wire appeared to be headed toward the aorta, so removal was decided upon.

The patient was readmitted to the Hospital on July 29, 1941. A gradual partial collapse of the right lung was accomplished by means of several small injections of air into the pleural cavity by Edgar Ricen, M.D., on August 11, 1941 (Fig. 1-D).

On August 12, 1941, F. R. Hook, M.D., removed the wire through an anterior incision with division of the costal cartilages of the second, third, and fourth ribs, and subperiosteal removal of one inch of the third rib. The lung was found to be about 80 per cent. collapsed, and there was one small adhesion between the upper lobe and the posterior chest wall (possibly the place of entrance of the wire). When the posterior surface of the lung was reflected forward, a tiny tit was seen in the lower portion of the upper lobe and beneath it the tip of the wire was palpable. A small nick was made in the pleura here, the wire was grasped with forceps, and removed. The incised pleura was closed with a figure-of-eight fine silk suture. The second and fourth costal cartilages were held in anatomical position by mattress sutures of chromic gut across their line of division. The wound was closed tightly and a firm compression bandage was applied. The wire was fifty-two millimeters in length.

The patient made a rapid and uncomplicated recovery. No air escaped into the chest wall. On the eighth day 950 cubic centimeters of serosanguinous fluid was aspirated from the right chest. Roentgenograms following aspiration on August 20, 1941, showed almost complete expansion of the lung, with some fluid remaining at the base. The man was allowed up on the eleventh day, and complained of only a little feeling of constriction of the chest. On the thirteenth day, seventy-five cubic centimeters of serosanguinous fluid was removed, and on the twenty-second day thirty cubic centimeters. Five weeks after removal of the wire, he had no complaints, was going on liberty, and was anxious to return to duty. Roentgenograms on September 19, 1941, showed complete expansion of the lung with practically no remaining fluid in the chest. The costal cartilages had firmly united. He returned to duty on September 26, 1941.

On October 13, 1941, the patient returned for follow-up. He was doing his regular duty; had no complaints; and roentgenograms showed complete aeration of the right lung without any fluid.

Four months following removal of the wire from the lung, he stated he had been in perfect health during the interim. There were no signs of pathology in the chest.

The following case is one of W. S. Wood's, M.D., of Decatur, Illinois, and is reported by his courtesy:

A sixteen-year-old white female, with a right shoulder flail from an old poliomyelitis, was admitted to the Decatur and Macon County Hospital in March 1938, through the Division of Handicapped Children of the State of Illinois.

On March 25, Dr. Wood fused the shoulder, using three Kirschner wires, and passing them through the humeral head and into the glenoid to maintain position. The ends of the wires protruded about two inches beyond the skin (Fig. 2-A). A plaster spica was applied.

The patient was discharged from the Hospital April 8, 1938.

She returned for a follow-up visit on August 4, 1938, but was not seen by the operator on that date. Roentgenograms showed good fusion of the shoulder. The wires and plaster were removed by an assistant, and the arm was placed in an airplane splint.

Some time later, the operator viewed the roentgenograms taken on August 4, and noted what appeared to be a portion of wire in the right chest. He interrogated the assistant, who said that he had recovered two wires from the shoulder, and had so stated on the record.

The patient was sent for at once. A series of roentgenographic and fluoroscopic studies disclosed the missing wire, with its pointed end just beneath the left second rib in the anterior axillary line, and its following end in the right lung. The wire lay athwart the left lung and mediastinum, and the portion embedded in the right lung moved with respiration (Fig. 2-B).

There was no roentgenographic evidence of reaction about the wire. The patient had had no symptoms of any nature, save for a slight pain in the left upper chest for one week, about two weeks prior to the removal of the plaster (sixteen weeks after operation). There was no cough, fever, or other discomfort.

On September 10, an incision was made along the lower border of the second left rib, the periosteum was stripped back, and the tip of the wire was felt. It was readily removed with an instrument. There was no postoperative reaction, and the wound healed readily. Roentgenograms taken September 16, 1938, showed some pleural reaction, and extravasation of fluid in the left chest. She returned home September 24.

Some pleural reaction persisted, as shown in roentgenograms taken on October 27, 1938.

Roentgenograms taken June 20, 1939, showed normal pulmonary patterns on both sides of the chest. The girl was in excellent health at this time; the shoulder was solidly fused; and she was leading a normal life.

DISCUSSION

In the first case, it is of academic interest to speculate on the course taken by the wire as it passed from the site of insertion to the site of removal. The complaint of occasional pain beneath the scapula, and the small adhesion of lung tissue to the posterior chest wall, found at operation, constitute the only clues as to its course. These suggest that it worked out through the clavicle near its center—the sharp end pointed medially of course—and then passed down along the posterior chest wall to traverse the interpleural space at the point where the adhesion was noted, entering the lung parenchyma there. Apparently it escaped penetrating any sizable bronchi or vessels within that organ, as no symptoms of such penetration were observed. No gross foreign-body reaction was observed in the tissue about the wire at operation or by roentgenogram. The wire itself showed no change.

In Dr. Wood's case, the course taken by the wire was obviously a straight one. Here again, the threat to the mediastinal structures failed to materialize. It can be reasonably supposed that had this wire not been removed, it would have worked its way out through the opposite chest wall. In this instance, the patient was aware of the two wires protruding

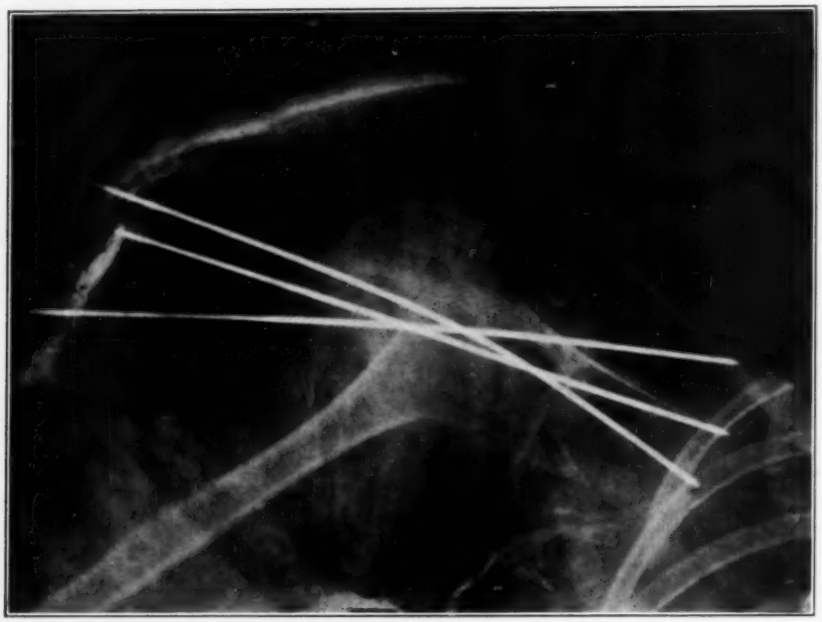

FIG. 2-A

Case 2. April 4, 1938. Roentgenogram shows three Kirschner wires passed through the fused shoulder.

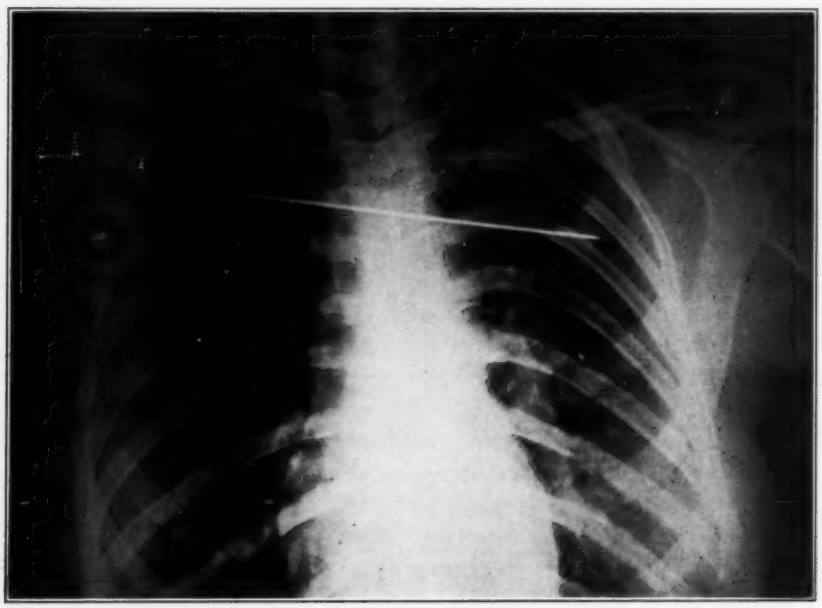

FIG. 2-B

September 9, 1938. One wire is traversing the mediastinum and both lungs.

from the plaster, but was not cognizant of the presence of the third wire, since it was not evident externally. This, and the fact that the doctor who removed the wires was unacquainted with the number which had been inserted, explain the lack of realization of the loss of one wire at the time the others were extracted.

The activating force which initiates and maintains locomotion in these cases can only be surmised. Muscle action may have acted in the rôle of masseuse in the first case, but could hardly have played a significant part in Dr. Wood's case, because of the paralysis and immobilization in plaster.

Whether or not such ill-understood phenomena as electrolysis and capillary attraction could have influenced the migration of the wires is not known.

It is notable that these wires and pins sometimes penetrate more deeply, following their pointed ends, and sometimes back out.

There are no rules governing the behavior of foreign bodies in the tissues. When sterile, they may lie dormant for years. They appear to move about without plan or reason. The symptoms of their presence are, for the most part, dependent on the complications they instigate.

CONCLUSIONS

Two instances of the migration of a Kirschner wire from the shoulder region into the lung indicate the danger of the presence of an unanchored sharp-pointed foreign body in the tissues. It appears that if wires are employed for fixation, some form of nut or stop which will prevent migration of the wire is necessary, and that the wires should be subsequently removed.

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Wood, W. S.: Personal Communication.

BARCLAY WELLINGTON MOFFAT

Dr. Barclay Wellington Moffat died at his home in Red Bank, New Jersey, on October 28, 1942. His was a quiet death as his had been a quiet life. Although for many years he had been a member of The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, and the American College of Surgeons, it is doubtful that he was known personally to more than a handful of his colleagues, for his was a retiring nature. He rarely participated in discussion; he preferred to listen rather than to speak. He was glad to learn from others, so that he could apply their experiences to his own patients. His quiet air was a surface phenomenon; beneath it was an active, energetic nature which could not rest unless engaged in combating crippledom and disease.

Dr. Moffat was born on July 9, 1890, in Orange, New Jersey. He was graduated from Harvard University in 1912, and from that University's Medical School in 1916. During his postgraduate training he had the unusual opportunity of interning at four New York hospitals: Bellevue Hospital, Hospital for the Ruptured and Crippled, Coney Island Hospital (Brooklyn), and Seaside Hospital of St. John's Guild (New Dorp).

During World War I, he was in active service with the 80th Division, 305th Field Artillery, the 320th Ambulance Company, 318th Field Hospital, and Triage Hospital of the American Expeditionary Force as orthopaedic surgeon, and participated in the Somme offensive at St. Mihiel, and in the Argonne-Meuse campaign. His rank in the Medical Reserve was that of Major.

After the Armistice, he remained in France where he interned at the Hôpital des Enfants Malades and the Hôpital Vaugirard in Paris, and attended the University of Paris and the Calôt Cliniques of Paris and Berck-Plage.

Thus prepared for his specialty, he returned to this country early in 1920. Here he combined private practice with work at a number of hospitals: New York Post-Graduate Medical School and Hospital, Hospital for the Ruptured and Crippled, Broad Street Hospital (Philadelphia), Seaside Hospital of St. John's Guild, and the Monmouth Memorial Hospital at Long Branch, New Jersey.

At the time of his death he was: Associate Attending Orthopaedic Surgeon on the staff of the New York Post-Graduate Medical School and Hospital (Columbia University); Attending Orthopaedic Surgeon at the Fitkin Memorial Hospital (Neptune, New Jersey), and Riverview Hospital (Red Bank, New Jersey); Consulting Orthopaedic Surgeon at Allenwood Sanatorium (Allenwood, New Jersey), Betty Bacharach Home for Afflicted Children (Longport, New Jersey), and Children's Country Home (Westfield, New Jersey); and Consulting Orthopaedic Surgeon and Medical Director of the New Jersey State Commission for Crippled Children.

Dr. Moffat has made a number of contributions to this *Journal:* In 1928, "The Operative Treatment of Scoliosis"; in 1929, "Köhler's Disease of the Patella"; in 1933, "Enlargement of the Intervertebral Disc Associated with Decalcification of the Vertebral Body: A Compensatory Hypertrophy"; in 1934, "A Demountable Kirschner Wire Guide for Use with the Albee Motor". In addition, he wrote numerous articles which appeared in other journals,—such as *The Journal of the American Medical Association, Surgery, Gynecology and Obstetrics, Archives of Surgery,* and *The Journal of the Medical Society of New Jersey.*

He was greatly interested in the problems of traumatic surgery, as indicated by the titles of the following articles: "Fractures of the Mid-Thigh", "Separation of the Acromio-Clavicular Joint", "Fractures of the Neck of the Femur", "Fractures about the Ankle Joint", "Bimalleolar Fractures", and "Pathologic Fractures of the Spine".

In his modest way, Dr. Moffat was typical of thousands of physicians who, shunning the limelight of publicity, do their work conscientiously, strive hard to heal the sick, and thus earn the love and gratitude of their patients.

News Notes

At the meeting of the Executive Committee of **The American Orthopaedic Association,** held in Chicago on Sunday, January 17, Dr. Murray S. Danforth of Providence, Rhode Island, was appointed Editor of *The Journal.*

Dr. John Siegling, formerly orthopaedic surgeon at the Carle Hospital Clinic, Urbana, Illinois, has been appointed Assistant Professor of Orthopaedic Surgery at the Medical College of South Carolina. His office is at 105 Rutledge Avenue, Charleston, South Carolina.

Extra copies of the reprints of the **"Progress in Orthopedic Surgery",** published in the September, October, and November 1942 issues of *Archives of Surgery* may be purchased for $1.00 per copy from the office of *Archives of Surgery,* 535 North Dearborn Street, Chicago, Illinois.

The Executive Board of the **American Public Health Association** announces that the Association will sponsor a three-day Wartime Public Health Conference in New York, N. Y., October 12, 13, and 14, 1943. The Seventy-Second Annual Business Meeting of the Association will be held in connection with the conference.

The Fourth International Assembly of the **International College of Surgeons** will be held on June 14, 15, and 16 at the Waldorf Astoria Hotel in New York, N. Y. The program will be devoted to war surgery and rehabilitation, and will be of interest not only to those directly connected with medicine, but also to the lay public.

Representatives from the United Nations, who are expected to attend, will give outstanding examples of the progress being made in war surgery and rehabilitation under battle conditions by their respective countries.

Dr. Max Thorek is the International Executive Secretary.

The **American Association of Industrial Physicians and Surgeons,** the **American Industrial Hygiene Association,** and the **National Conference of Governmental Hygienists,** representing the medical, surgical, and industrial hygiene experts, are combining their Annual Meetings in a four-day "War Conference" at Rochester, New York, May 24 to 27, 1943.

This joint meeting will be a report on the state of the nation in matters of industrial health. Dr. William A. Sawyer, Medical Director of Eastman Kodak, is General Chairman; Dr. James H. Sterner and Lieutenant Commander J. J. Bloomfield are arranging the program for the industrial hygienists. All who are interested in the problems of industrial health and their solution are invited to attend the sessions.

The **Washington Orthopaedic Club** includes orthopaedic surgeons in the city of Washington and also Army surgeons engaged in this specialty at the Walter Reed Hospital and Navy surgeons connected with the Naval Hospital at Bethesda, Maryland.

At the meeting of this society on December 14, 1942, the following officers were elected:

President: Julius Nevaiser, M.D., Washington, D. C.

Vice-President: Paul O'Donnell, M.D., Naval Hospital, Bethesda, Maryland.

Secretary-Treasurer: Julius J. Radice, M.D., Washington, D. C.

Members elected to the **British Orthopaedic Association** during the past year include the following: Mr. H. E. Griffiths (Full Member), Mr. John Adams (Flight Lieut.), Mr. Harold Cantor (Flight Lieut.), Mr. R. C. F. Catterall, Mr. James E. Cawthorne (Flight Lieut.), Mr. John Craw, Mr. E. J. Crisp, Mr. C. H. Cullen, Mr. John M. Fitton, Mr. S. F. H. Haughton, Mr. R. W. Higgins (Surg. Commander), Mr. A. Innes, Mr. O. J. Vaughan Jackson (Surg. Lieut. Commander), Mr. John I. P. James, Mr. Cecil D. Langton, Mr. W. McKechnie, Mr. J. E. Monro, Mr. D. F. E. Nash (Squadron Leader), Mr. A. Naylor, Mr. B. O'Neill, Major Harold J. Spooner, Mr. S. Stanford, Mr. R. C. Tatham, Mr. B. M. Unkauf, Mr. Andrew Zinovieff (Flight Lieut.).

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The American Orthopaedic Association will hold its Annual Meeting in Cleveland under the presidency of Dr. Frank R. Ober, on June 7 and 8, 1943, and the headquarters will be at the Hotel Cleveland. The program will include the following papers:

Some Lipoid Disorders Involving Bones.
Dr. Sidney Farber, Boston, Massachusetts.

Peripheral Nerve Pathology Associated with Congenital Deformities.
Dr. Beveridge H. Moore, Chicago, Illinois.

Experiences with the Kenny Treatment for Acute Poliomyelitis in the Epidemic of 1942, Monmouth and Ocean Counties, New Jersey.
Dr. Nicholas S. Ransohoff, New York, N. Y.

The Significance of the Iliocostal Fascial Graft in Paralytic Deformities of the Trunk
Dr. Leo Mayer, New York, N. Y.

Subastragalar Arthrodesis in Fractures of the Os Calcis.
Dr. W. E. Gallie, Toronto, Ontario, Canada.

Anterior Capsuloplasty of the Elbow for the Relief of Flexion Contractures following Fractures of the Lower End of the Humerus.
Dr. Philip D. Wilson, New York, N. Y.

President's address.
Dr. Frank R. Ober

End-Result Study of 100 to 200 Cases of Herniated Nucleus Pulposus.
Dr. Edwin M. G. Deery and Dr. Alan DeForest Smith, New York, N. Y.

Solitary Bone Cyst.
Dr. Samuel Kleinberg, New York, N. Y.

Results in Fifty Cases of the Use of the Clothespin Graft for Spondylolisthesis, Laminal Defects, or Disc Defects of the Lumbar Spine.
Dr. David M. Bosworth, New York, N. Y.

Local Shock and Block of Sympathetics on Circulatory Phenomena in an Injured Extremity.
Dr. J. E. M. Thomson, Lincoln, Nebraska.

Shock in Extremity Surgery.
Dr. Dallas B. Phemister, Chicago, Illinois.

Chronic Bone Infection and Sulfonamides.
Dr. J. Albert Key, St. Louis, Missouri.

Talk on Shoulder (exact title not yet known).
Dr. Harrison L. McLaughlin, New York, N. Y.

Certain Aspects of the Anatomy of the Shoulder and Some New Concepts about the Functional Anatomy about the Shoulder Joint.
Dr. LeRoy C. Abbott, Dr. John B. deC. M. Saunders, and Dr. Verne T. Inman, San Francisco, California.

Preparation of Specimens for Orthopaedic Teaching.
Dr. John B. deC. M. Saunders, San Francisco, California.

Delayed Reduction of Fractures.
Dr. John Royal Moore, Philadelphia, Pennsylvania.
Title to be announced.
Dr. A. Bruce Gill, Philadelphia, Pennsylvania.
Orthopaedics in Aviation Medicine.
Dr. John Fulton, New Haven, Connecticut.

Executive sessions will be held at noon each day.

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

Due to wartime conditions, The Eleventh Annual Convention of **The American Academy of Orthopaedic Surgeons** was held at the Palmer House, Chicago, January 17, 18, 19, and 20, 1943, combined with the Thirtieth Annual Meeting of **The Clinical Orthopaedic Society.** The Presidents of the two organizations, Carl E. Badgley, M.D., Ann Arbor, Michigan, and Ralph Ghormley, M.D., Rochester, Minnesota, presided over the sessions of their respective societies.

Monday, January 18, was a clinical day, and the program was planned by the Chicago members of The Clinical Orthopaedic Society. The following presentations were made:

Morning Session

Traumatic Vascular Lesions and Their Effects.
Dr. Donald S. Miller.
Compression Fractures in Demineralized Vertebrae.
Dr. Edwin W. Ryerson.
Complications following Fractures of Pelvis.
Dr. Harry E. Mock.
Amputation at the Knee Joint.
Dr. S. Perry Rogers.
Excision of Fractured Patellae.
Dr. John R. Norcross.
Internal Fixation in Spiral Fractures of the Tibia.
Dr. Carlo Scuderi.
Treatment of Os Calcis Fractures.
Dr. Manly A. Page.
1. Hip Fusion for Tuberculosis (Chandler Operation).
2. Plasma Cell Myeloma of the Spine.
3. Bilateral Legg's Disease in Two Brothers.
Dr. Charles N. Pease.
Unusual Infantile Paralysis Cases.
Dr. Beveridge H. Moore.
Etiology and Surgical Treatment of Morton's Toe.
Dr. R. T. McElvenny.

Afternoon Session

1. Malignancy of Hip Joint. Treatment by Disarticulation of Hip.
2. An Interesting March Fracture in a Fifteen-Year-Old Girl.
3. Spondylolisthesis with Sciatica. Treatment by Spine Fusion.
Dr. Frank Glassman.
1. Arthroplasty of the Elbow.
2. Neurinoma of the Foot.
3. Cocoanut-Oil Derivatives as a Cleansing Material in Emergencies.
Dr. Emil D. W. Hauser.

1. Severe Fractures or Fracture Dislocations of the Neck of the Humerus.
2. Scalenus Anticus Syndrome. Simplified Technique for Tenotomy.
   Dr. Daniel H. Levinthal and Captain Irving Wolin, M. C., U. S. Army.
1. Disturbances in Calcium Metabolism.
2. Complications in Nailing Fractured Neck of Femur.
   Dr. Ferdinand Seidler.

Local Resection and Massive Bone Transplantation in Treatment of Bone Sarcoma.
Dr. Dallas B. Phemister.

Treatment of Bone Metastasis in Carcinoma of the Prostate.
Dr. Charles B. Huggins.

Erosion of Lamina Associated with Congenital Anomalies of the Spine.
Dr. A. Earl Walker.

Growth Arrest as Cause of Recurrent Deformity in Club-Foot.
Dr. Mary S. Sherman.

Cases of Femoral Shortening.
Dr. Robert D. Moore.

Postirradiation Bone Sarcoma.
Dr. C. Howard Hatcher.

The program as planned by the Program Committee of The American Academy of Orthopaedic Surgeons began with the Tuesday morning session and included the following papers:

TUESDAY, JANUARY 19

Morning Session

Transiliac Amputation.
Dr. Don E. King, San Francisco, California.

Non-Union Resulting from Two-Pin Skeletal Traction.
Dr. Arthur G. Davis, Erie, Pennsylvania.
Dr. Clayton W. Fortune, Erie, Pennsylvania.

The Treatment of Difficult and Unusual Non-Unions, with Special Reference to the Bridging of Defects.
Dr. Harold B. Boyd, Memphis, Tennessee.

Importance of Leaving a Good Amputation Stump.
Dr. A. B. LeMesurier, Toronto, Ontario, Canada.

Treatment of Non-Unions of Gunshot Fractures with and without Loss of Substance.
Dr. Fred H. Albee, New York, N. Y.

Afternoon Session

Local Excision and Massive Transplantation in a Selected Series of Sarcomata Involving the Long Bones.
Dr. Dallas B. Phemister, Chicago, Illinois.

Organization of the Medical Services in the Army Air Forces.
General D. N. W. Grant, M. C., U. S. Army, Washington, D. C. (by invitation).

This War and the Orthopaedic Surgeon.
Dr. Guy W. Leadbetter, Washington, D. C.

Total Carpectomy for Intractable Wrist Flexion.
Dr. J. Warren White, Greenville, South Carolina.

Correspondence from Members Abroad, prepared by Lieutenant Colonel Rex L. Diveley, M. C., U. S. Army, Senior Consultant in Orthopaedic Surgery, read by Dr. Myron O. Henry, Minneapolis, Acting Secretary.

WEDNESDAY, JANUARY 20

Morning Session

Motions of the Hip Joint.
Dr. John W. Ghormley, Albany, New York.

Neglected Femoral Fractures.
Major Leonard T. Peterson, M. C., U. S. Army, Washington, D. C.
Blade-Plate Internal Fixation for High Femoral Osteotomies.
Dr. Walter P. Blount, Milwaukee, Wisconsin.
Fractures of the Os Calcis. Principles of Treatment with Improved Technique and the Results Obtained by It.
Dr. R. I. Harris, Toronto, Ontario, Canada.
The Status of Orthopaedic Surgery in the Army Air Forces.
Major Alfred R. Shands, M. C., U. S. Army, Wilmington, Delaware
Osteochondritis Dissecans of the Patella.
Major Francis J. Cox, M. C., U. S. Army, Fort Benning, Georgia (by invitation).
Spastic Paralysis and Its Allied Conditions.
Dr. H. R. McCarroll, St. Louis, Missouri.
Dr. John R. Schwartzmann, St. Louis, Missouri (by invitation).
A Civilian Surgeon's Evaluation of Achievements and Mistakes.
Dr. Francis J. Halford, Honolulu, T. H. (by invitation).

Afternoon Session

Complicating Trauma Associated with Orthopaedic Casualties.
Panel discussion led by Dr. Frederick A. Coller.
Shock—Early Recognition and Treatment.
Dr. Warren H. Cole, Chicago, Illinois.
Crush and Compression Injuries.
Commander Herbert L. Pugh, M. C., U. S. N., Washington, D. C.
Blast Injuries.
Lieutenant Commander John B. Hartzell, M. C., U. S. N. R., Detroit, Michigan.
Thoracic Injuries.
Dr. John Alexander, Ann Arbor, Michigan.
Head and Spine Injuries.
Dr. Eric Oldberg, Chicago, Illinois.
Abdominal Injuries.
Major Ambrose H. Storck, M. C., U. S. Army, Washington, D. C.
Injuries to Genito-Urinary Tract.
Dr. Reed M. Nesbit, Ann Arbor, Michigan.
Comments and Conclusions.
Dr. Frederick A. Coller, Ann Arbor, Michigan.

An important feature of the program this year was the "Refresher" Courses which were given in the early mornings and late afternoons. The subjects of these instructional courses and the faculty were:

Surgery of the Hand: Dr. Sterling Bunnell, and Dr. Sumner L. Koch (by invitation).

Fractures: Dr. H. Earle Conwell, Dr. Philip D. Wilson, Commander Herbert L. Pugh, M. C., U. S. N. (by invitation), Captain Camille M. Shaar, M. C., U. S. N. (by invitation), Dr. Robert D. Schrock, Dr. Will F. Lyon (by invitation), Colonel Jesse I. Sloat, M. C., U. S. Army, and Lieutenant Commander Douglas D. Toffelmier, M. C., U. S. N. R.

Peripheral Nerve Injuries: Lieutenant Colonel Roy G. Spurling, M. C., U. S. Army (by invitation), and Dr. Lewis J. Pollock (by invitation).

Amputations: Colonel Norman T. Kirk, M. C., U. S. Army, Dr. Philip D. Wilson, Dr. A. B. LeMesurier, Major T. Campbell Thompson, M. C., U. S. Army, Major Francis M. McKeever, M. C., U. S. Army, Dr. Vernon P. Thompson, Dr. Atha Thomas, and Lieutenant Commander James C. White, M. C., U. S. N. R.

The Lame Back: Dr. Ralph K. Ghormley, Major Roy G. Spurling, M. C., U. S. Army (by invitation), Dr. A. W. Adson (by invitation), and Dr. Alan DeForest Smith.

Surgery of the Hip: Dr. Oscar L. Miller, Dr. Herman C. Schumm, Dr. Lawson Thornton, Dr. Fred H. Albee, Dr. J. Warren White, Dr. Dallas B. Phemister, Dr. A. Bruce Gill, Dr. Paul C. Colonna, Dr. Carl E. Badgley, Dr. M. N. Smith-Petersen, and Dr. Paul B. Steele.

Surgery of the Knee: Dr. Allen F. Voshell, Major Wallace S. Duncan, M. C., U. S. Army, Captain William F. Stanek, M. C., U. S. Army (by invitation), Dr. Philip D. Wilson, Dr. Frank M. Hand, Dr. William R. Cubbins (by invitation), Major Vernon L. Hart, M. C., U. S. Army, and Dr. Fremont A. Chandler.

Burns and War Plastic Procedures: Colonel Grover C. Penberthy, M. C., U. S. Army (by invitation), Lieutenant Commander Ralph C. Pendleton M. C., U. S. N. R. (by invitation), Captain H. L. D. Kirkham, M. C., U. S. N. R. (by invitation), Dr. A. W. Farmer (by invitation), and Dr. Henry Harkins (by invitation).

Foot Disabilities: Dr. J. Warren White, Dr. Emil D. W. Hauser, Lieutenant Commander James C. White, M. C., U. S. N. R. (by invitation), Captain Wesley H. Burnham, M. C., U. S. Army (by invitation), Lieutenant Commander C. Fred Ferciot, M. C., U. S. N. R.

Differential Diagnosis of Bone Pathology: Dr. Henry W. Meyerding, Dr. Herman F. Johnson, Dr. William Carpenter MacCarty, Sr. (by invitation), Dr. Charles P. Baker (by invitation).

Reconstructive Surgery following Trauma of the Upper Extremity: Dr. Arthur Steindler.

Surgical Anatomy, Upper Extremity: Dr. John J. Fahey.

Surgical Anatomy, Lower Extremity: Dr. John T. Reynolds (by invitation).

Complicating Trauma Associated with Orthopaedic Casualties: Because of the general interest in this course it was given as a panel discussion on the Wednesday afternoon session of the scientific program.

There were a large number of motion pictures given before and following the scientific sessions. These covered many subjects of interest to the attending surgeons.

The scientific exhibits were of a high order. These were in charge of a committee of which Dr. Edward L. Compere was chairman.

The annual banquet was held on Tuesday evening, January 19. General D. N. W. Grant spoke informally. The President gave his address which was on "Correlation of Clinical Anatomical Facts Leading to a Conception of the Etiology of Congenital Hip Dysplasias". Brigadier General W. Rowley Bristow of London was scheduled as one of the speakers at this session; unfortunately he did not arrive in Chicago in time for the meeting. At the evening session the awards of the society were presented as follows:

Gold Medal for Originality of Presentation of Research Problems, to Dr. John J. Fahey of Chicago, Illinois—"Circulation of the Femoral Head".

Gold Medal for Scientific Importance and Information, to Dr. H. Winnett Orr, of Lincoln, Nebraska—"History and Literature of Orthopaedic Surgery".

Gold Medal for Clinical Value, to Dr. Walter P. Blount, of Milwaukee, Wisconsin—"Blade-Plate Internal Fixation for High Femoral Osteotomies".

Certificates of merit were awarded to the following for their exhibits:

Dr. C. Howard Hatcher, Dr. Robert D. Moore, and Dr. Mary S. Sherman, of Chicago, Illinois—"Localized Fibrous Lesions of the Long Bones".

Dr. Paul H. Harmon of Sayre, Pennsylvania—"The Treatment of Fractures of the Tibia".

Dr. H. R. McCarroll and Dr. John R. Schwartzmann, of St. Louis, Missouri—"Spastic Paralysis and Its Allied Conditions".

Dr. Henry W. Meyerding, of Rochester, Minnesota—"Benign and Malignant Tumors of Bone".

Dr. S. Perry Rogers, of Chicago, Illinois—"Amputation at the Knee Joint—A Physiological Amputation".

Dr. Irving Stein, of Philadelphia, Pennsylvania—"Phases of Paget's Disease and Its Treatment".

Newly elected Fellows presented at the Meeting were:

Dr. Rufus H. Alldredge, New Orleans, Louisiana.
Dr. W. A. Bishop, Jr., Wichita Falls, Texas.
Dr. Carroll B. Buffington, Wheeling, West Virginia.
Captain Milton C. Cobey (of Washington, D. C.), Keesler Field, Mississippi.
Dr. E. W. Cullipher, Miami, Florida.
Dr. Leonard R. Donne, Brooklyn, New York.
Dr. E. W. Ewart, Moncton, New Brunswick, Canada.
Dr. John J. Fahey, Chicago, Illinois.
Dr. Reginald C. Farrow, Syracuse, New York.
Dr. Charles J. Frankel, Charlottesville, Virginia.
Dr. Heywood H. Hopkins, Rochester, New York.
Dr. John V. Hopkins, Baltimore, Maryland.
Captain Frederic W. Ilfeld, Camp Callan, California.
Dr. Julian E. Jacobs, Charlotte, North Carolina.
Dr. Abel Kenin, Brookyn, New York.
Dr. Daniel M. Killoran, Lynn, Massachusetts.
Dr. Carroll Bernard Larson, Boston, Massachusetts.
Dr. Harold Gordon Lee, Boston, Massachusetts.
Dr. Arthur B. LeMesurier, Toronto, Ontario, Canada.
Dr. Gottlieb S. Leventhal, Philadelphia, Pennsylvania.
Dr. Thomas Albert Martin, Portland, Maine.
Dr. Ralph R. Morral, Youngstown, Ohio.
Dr. Robert L. Noell, Oklahoma City, Oklahoma.
Dr. Herschel Penn (of Knoxville, Tennessee), Jacksonville, Florida.
Dr. Edwin B. Plimpton, Los Angeles, California.
Dr. John A. Reidy, Boston, Massachusetts.
Major George H. Ryan, Hamilton, Ontario, Canada.
Dr. Eugene W. Secord, Detroit, Michigan.
Dr. Penelope Sherwood, Newburgh, New York.
Dr. Dudley W. Smith, Waynesville, North Carolina.
Captain O. Sherwin Staples (of Boston), Camp Livingston, Louisiana.
Dr. William Curry Sullivan, Rochester, New York.
Dr. Frederick B. Thompson, New York, N. Y.
Dr. Luis Barboza Viana, Rio de Janeiro, Brazil.

Two doctors were elected to Honorary Membership: Dr. Frederick S. Coller, Ann Arbor, Michigan, and Dr. Alton Ochsner, New Orleans, Louisiana.

At the close of the session, the President presented Dr. M. N. Smith-Petersen, President-Elect, who spoke briefly.

The executive sessions of The Academy were held at noon on Tuesday and Wednesday. At the second session, new officers and committees for the year were elected. The new officers of The Academy are:

President: Dr. M. N. Smith-Petersen, Boston, Massachusetts.
President-Elect: Dr. E. Bishop Mumford, Indianapolis, Indiana.
Vice-President: Dr. Arthur G. Davis, Erie, Pennsylvania.
Treasurer: Dr. Fremont A. Chandler, Chicago, Illinois.
Secretary: Dr. Myron O. Henry, Minneapolis, Minnesota.
Librarian-Historian: Dr. Edward L. Compere, Chicago, Illinois.

The Twelfth Annual Convention of The Academy will be held in Chicago, in January 1944.

THE AMERICAN BOARD OF ORTHOPAEDIC SURGERY

At its Annual Meeting in Chicago, January 17, 1943, the American Board of Orthopaedic Surgery began a revision of its rulings pertaining to applications, examinations, and the fee schedule. These changes will be completed and confirmed at an early

meeting of the Board. The revised rulings will then be published and distributed by July, 1943, so that prospective candidates may be governed accordingly. The dates of future examinations will be published at the same time.

Under the revised by-laws, the examination will be divided into Parts I and II. Applicants who have completed a rotating internship and one or two years of resident training in orthopaedic surgery, or their equivalent in military service, will be eligible for Part I of the examination. This part will cover the basic sciences, fundamentals of surgery, and elementary principles of orthopaedic and fracture treatment with oral interviews and written examination. Tentative plans provide that Part I may be given during the fall months in four different centers, probably in New York, Chicago, New Orleans, and San Francisco.

Part II of the examinations will probably be given, as heretofore, only once a year, in connection with the meeting of The American Academy of Orthopaedic Surgeons. Applicants for Part II must have completed their full requirements for eligibility, including their practice periods. The written examination and oral interviews will include advanced operative technique, standard orthopaedic procedures, reviews of the literature, case records, *et cetera*.

Orthopaedic Service Record: Certification by the Board will follow successful completion of Part II of the examination. In order that the Committee on Eligibility may have adequate data for evaluation of the training of applicants who have served with the Armed Forces, a plan will be set up whereby all who are assigned to orthopaedic services will be provided with an Orthopaedic Service Record. These records must indicate the character and amount of orthopaedic work performed at each post to which prospective applicants are assigned. The notations of each officer concerning his service at each post must be signed by his superior officer in charge of the orthopaedic service and approved by the Commanding Officer. The Orthopaedic Service Record will be retained by the officer and finally will be submitted with his application to the Board for review by the Committee on Eligibility.

Fees: The fee schedule is being revised to cover the changes brought about by instituting Parts I and II of the examination.

The Board's Committee on Resident Training and Hospital Services will endeavor to reach all men now taking orthopaedic training in civilian hospitals, as well as those assigned to orthopaedic services with the Armed Forces, and will provide them with the copies of the revised rulings and the Orthopaedic Service Record, by July 1, 1943. Medical officers now in service and assigned to orthopaedic services are requested to write the Secretary for this information.

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Current Literature

ILLUSTRATIONS OF SURGICAL TREATMENT. INSTRUMENTS AND APPLIANCES. Eric L. Farquharson, M.D., F.R.C.S.E. With a Foreword by Sir John Fraser, M.C., M.D., Ch.M., F.R.C.S.E. Ed. 2. Baltimore, The Williams and Wilkins Co., 1942. $7.00.

The title is somewhat misleading, although perfectly understandable from the British viewpoint, since it deals almost entirely with fractures and a few orthopaedic conditions. It is written with the idea of giving assistance to house surgeons and to those "reading for higher examinations", but is well worthy of study by surgeons of wider experience. In a compact and clear-cut text, the treatment of the injuries of the vertebral column and ribs, the shoulder girdle and upper extremity, and the pelvic girdle and lower extremity are described in a satisfactory manner. Tuberculosis of the spine and hip joint, traumatic and congenital dislocation of the hip joint, and the manipulative treatment of injuries of the knee joint are described in separate chapters. No attempt is made to discuss the etiology and diagnosis of the above conditions. On the other hand the numerous illustrations and line drawings, which so ably supplement the text, serve to answer any questions which might arise, and clearly explain the methods employed. The illustrations constitute one of the most valuable features of the book. Only recognized and, in general, conservative procedures are advocated. It is in this manner that the illustrations prove their value, since they interpret so clearly the subject matter of the text. An introductory chapter describes modern methods of intravenous infusion, and transfusion of blood and protein fluids. An appendix contributes illustrations, in catalog form, of a complete assortment of surgical instruments of all types. The principles of treatment recommended are usually sound, simple, and practical, but in at least one instance there has been a departure from established procedure. Splinting a fracture of the upper end of the tibia entering the knee joint, with a plaster cast extending from the upper thigh to the lower border of the calf muscles is a departure from the approved practice of fixing both the joint above, as well as that below, the fracture. The volume, as a whole, is to be highly recommended as a book of handy reference, and one full of useful information.

FRACTURES. Paul B. Magnuson, M.D., F.A.C.S. Ed. 4. Philadelphia, J. B. Lippincott Co., 1942. $5.50.

When a fracture text passes through four editions in the course of ten years, as has this one, it obviously appeals to the medical reading public. It is "written in an endeavor to meet the needs of the man who first sees the fracture". This edition includes some new material on first aid, transportation, and early treatment of compound fractures, but, otherwise, remains essentially the same as previous editions. It is primarily a record of the method of treatment which the author uses for the various fractures and dislocations. It is written in a direct, clear, forceful style, and is well illustrated by drawings and roentgenographic reproductions. The author describes, as a rule, only one method of treatment for each type of fracture,—"there may be some that are better, but these have worked". The methods which he describes are sound, but, in certain instances, will appear to be somewhat old-fashioned. The use of ice-tong calipers, for instance, or of the Steinmann pin, which he recommends for traction in femoral supracondylar fractures, has been superseded by Kirschner-wire traction in most clinics.

The author describes the technique of a number of his own operations. There are many features of the book which will interest the accomplished surgeon as well as the student.

TREATMENT OF FRACTURES. Guy A. Caldwell, M.D., F.A.C.S. New York, Paul B. Hoeber, Inc., 1943. $5.00.

Interest in the treatment of fractures has been stimulated by the increase in the number of injuries of the spine and of the extremities from industrial accidents, automobile traffic, and more recently from major engagements between armed forces in all parts of the world. This volume is not intended to be an encyclopaedic reference book. As stated by the author, it is planned for the medical student and the general practitioner. Much that is controversial has been deliberately omitted. The author has discussed the methods which he, himself, has found to be most practicable in his own private practice.

All of the illustrations are artists' drawings. They have been very well prepared, although many procedures which are discussed are not illustrated.

Primarily this text deals with the problem of therapy, and, as such, it constitutes a worthy addition to the rapidly growing number of books on fractures. It may be very safely recommended to medical students or general practitioners, or any others who are interested in the clinical problem of fractures.

FRACTURES OF THE JAWS AND OTHER FACIAL BONES. Glenn Major, D.D.S., M.D. With Chapters on Radiographic Technic by Lester M. J. Freedman, M.D., and War Aspects of Jaw Fractures by Arthur Dick, D.D.S., M.D. St. Louis, The C. V. Mosby Co., 1943. $7.50.

This book is one of several monographs on fractures of the jaws published in the last year. The emphasis is on fractures producing malocclusion,—that is, all types of fractures of the mandible and the relatively rare transverse fractures of the maxilla. There is only the briefest consideration of fractures involving the nose, malar bones, and zygomatic arches. About one-third of the text is concerned with a review of the various methods of interdental fixation. The author indicates in which type of fracture each method is suitable. There is no mention of any of the more recent extra-oral appliances. The book is illustrated with sketches by the author and a few photographs and roentgenograms. In the chapter on radiographic technique the poses for adequate roentgenographic studies of the jaws and bones of the face are well illustrated. There is a good bibliography at the end of the book, but there is no reference to the authors of these papers in the text. The author is to be complimented on his stand regarding the extraction of teeth in the line of fracture. For those interested in a general consideration of fractures of the jaws and methods of intra-oral fixation, this book should be of interest.

THE 1942 YEAR BOOK OF INDUSTRIAL AND ORTHOPAEDIC SURGERY. Edited by Charles F. Painter, M.D. Chicago, The Year Book Publishers, 1942. $3.00.

It is impossible to review a book that is, in itself, a review, but the editor should be commended for his choice of subjects, his clearness of exposition, and for his very valuable and fair comments on new and controversial reports.

The book seems to keep the reader informed on almost every feature that is new or pertinent to these specialties.

ÜBER TOTALEXSTIRPATIONEN DER PATELLA (Total Extirpation of the Patella). Sten Friberg. *Acta Chirurgica Scandinavica*, LXXXV, 361, 1941.

The author reports thirty-two cases of complete removal of the patella. The indication was chondromalacia, comminuted fractures, or certain simple fractures which had failed to respond to conservative therapy. Operative methods are described. In twenty-six cases, the quadriceps tendon was sutured to the patellar ligament. Of the thirty-two patients, thirteen (40.6 per cent.) had excellent, that is, symptom-free joints which could stand severe work strains without tiring; fourteen (43.8 per cent.) were free from symptoms in ordinary activity, but had inadequate strength in greater stress and some

insecurity in walking on uneven ground. The latter, however, considered themselves much improved by the operation. Function was essentially complete, therefore, in 84 per cent. of the cases. Follow-up period averaged twenty-one months. There was an average of 1.9 centimeters of atrophy of the thigh. In all cases where tendon suture had been done, the patient had complete extension; four of the other six, where it was not done, also had complete extension. There was a positive drawer's sign in twenty cases, and very slight calcified deposits at the site of the patella in twenty-six cases. In two such cases the deposits were large and gave rise to pain. The smaller the calcified deposit, when present, the better the result.—*I. M. Zeligs, M.D., Iowa City, Iowa.*

Diagnosis and Treatment of the Ligaments of the Knee Joint in Ligamentous Injuries to the Knee Joint. Sophus von Rosen. *Acta Orthopaedica Scandinavica*, XII, No. 1–4, 1941.

Injuries to the ligaments of the knee joint are usually not solitary lesions, but are a combination of injuries, a frequent combination being injury to the anterior cruciate combined with injury to the tibial collateral ligament and the medial meniscus. An immediate correct diagnosis is usually made only in case of rupture of the lower part of the cruciate ligament, when the attachment of the ligament is torn loose together with a portion of bone. This injury can be demonstrated in the roentgenogram. If the bone fragment is displaced, reposition must be carried out and the fragment must be fixed in the correct position.

Four cases of such injuries were treated by open reposition and fixation of the bone fragment with catgut sutures drawn through drill holes in the tibial condyle.

In case of complete rupture of the posterior cruciate ligament, the author recommends an early operation which consists in suturing, because he believes that the backward dislocation of the leg brought about by the injury predisposes to arthritis deformans later. Prognosis of injury to the posterior cruciate is less favorable than that of injury to the anterior cruciate ligament. In other ligamentous injuries, particularly those of the collateral ligaments, he recommends conservative treatment which consists in immobilization for about three months. He also believes that with conservative treatment anatomical healing may be obtained in cases of partial rupture of the cruciate ligament as well as in rupture of the collateral ligaments. On the other hand, with conservative treatment, the complete rupture of the cruciate ligaments will not heal anatomically, though it may heal functionally, with no subjective or objective symptoms. The characteristic point in patients with untreated or inadequately treated injuries to the ligaments, who are not yet symptom-free, is the lack of active and passive stability of the knee joint. He believes that insufficiency of the injured collateral ligament, especially of the tibial collateral ligament, is the chief cause of this lack of stability of the knee, and that injury to the anterior cruciate ligament, with which it is so frequently associated, is only of minor importance in this regard. Most observers emphasize the importance of strengthening the medial collateral ligament at the same time that the ruptured cruciate ligament is repaired. In three cases, the author has replaced a completely ruptured anterior cruciate ligament with the medial part of the ligamentum patella, which was loosened from its upper attachment and introduced into the joint just above the tibial condyle and nailed to the inner side of the lateral condyle of the femur in a chiseled groove. He was able to satisfy himself in one of the cases, that upon removal of the nail a strong ligament had formed; in the other two cases, the stump of the ligament had not taken hold in its new insertion and was retracted.—*Helge Sjövall, M.D., Iowa City, Iowa.*

Children's Feet, Normal and Presenting Common Abnormalities. Fremont A. Chandler. *American Journal of Diseases of Children*, LXIII, 1136, 1942.

The author states that the medical profession has neglected the field of children's feet, and has left it to some of the cults, shoe manufacturers, and salesmen for develop-

ment, and in some instances exploitation. He urges both pediatricians and orthopaedic surgeons to be more aware of the problem. He discusses club feet, pronated feet, and cavus feet, and mentions other deformities. He believes that treatment of congenital club-foot by manipulation and casts should be begun early, preferably the first day of life.

Three functions of the normal foot gradually develop from birth, and reflect regular growth. A prehensile grasping function, similar to the prehensile reaction of the hand, is present at birth, but, unlike that of the hand, is usually gradually lost. Muscle coordination advances through the rolling and creeping stages to that of standing. Propulsion follows shortly, and a gait is established.

The mechanism of walking is described in some detail and is illustrated by drawings and photographs.

A good shoe for a growing foot should afford adequate protection against injury and extremes of temperature; plantar support similar to that afforded by the ground; and an interior which will permit unrestricted variation in size and movement of the foot during all phases of its function.

Osteochondrosis Deformans Tibiae. Nonrachitic Bow Leg in Children. C. Glenn Barber. *American Journal of Diseases of Children*, LXIV, 831, 1942.

The characteristics of osteochondrosis deformans tibiae are definite, and need not be confused with those of rickets, dyschondroplasia (Ollier's disease), achondroplasia, fragilitas ossium, or osteogenesis imperfecta. The roentgenographic and pathological changes are like those of coxa plana. Two distinct types—designated infantile and adolescent depending upon the age at onset—are described.

Because spontaneous recovery sometimes occurs in the milder forms of the infantile type, and because recurrence may take place if surgical correction is undertaken before the condition has become arrested, the author tried manipulation and counterpressure, and found that further deformity could be prevented, and some existing deformity could be corrected. He emphasizes that recurrence may be expected if correction is not maintained until the causative factor has become arrested. Tibial osteotomy may be necessary for correction once the condition has been arrested.

Two cases are reported.

Tuberculosis of the Greater Trochanter and Its Bursa. Mark S. Donovan and Merrill C. Sosman. *The American Journal of Roentgenology and Radium Therapy*, XLVIII, 719, 1942.

Bursitis lateral to the greater trochanter is a rare condition, and is frequently caused by tuberculosis involving the greater trochanter. Since this portion of the femur develops as an epiphysis, its cancellous bone is as susceptible to tuberculosis as the femoral head or other epiphyses. An important diagnostic point is the presence of tuberculosis in an active, inactive, or healed form in another part of the body.

The authors present the clinical, roentgenographic, operative, and histopathological findings in five cases of tuberculosis of the greater trochanter and the adjacent bursa. All the patients had had symptoms for at least one year before operation. The disease may develop at any age, but the symptoms usually begin during adolescence or early life. The characteristic features are a destructive lesion beginning in the upper part of the trochanter, with formation of a cold abscess and later a sinus. Bursitis is manifested by swelling of the soft tissues over the trochanter and amorphous calcium depositions just lateral to it.

Differentiation from acute infection and from tumors is seldom difficult. In the early stages a light roentgen exposure may be necessary to demonstrate the erosion of the normally thin cortex of the trochanter and the faint calcium deposits in the adjacent bursa. The disease frequently recurs after apparent cure by surgical extirpation.—*Richard C. Batt, M.D., Berlin, New Hampshire.*

DEVELOPMENT, CLINICAL MANIFESTATIONS, AND TREATMENT OF RHEUMATOID ARTHRITIS OF THE APOPHYSEAL INTERVERTEBRAL JOINTS. Albert Oppenheimer. *The American Journal of Roentgenology and Radium Therapy*, XLIX, 49, January 1943.

Lesions of the apophyseal joints frequently cause pain in the spine, and limitation of the vertebral movements. Rheumatoid changes in the apophyseal joints are the initial lesions of Marie-Strümpell arthritis. The latter disease does not always show lesions of the vertebral symphyses, rarefaction of the vertebral bodies, or ossification of the ligaments. Such changes are secondary developments and do not necessarily produce pain. Treatment in the early stages of this disease not only affords relief of symptoms, but may also prevent the invalidism of a permanent spondylitis.

The author's theory is supported by roentgenographic studies of the entire spine with clinical findings in fifty cases of rheumatoid arthritis of the apophyseal joints which he diagnosed while in Beirut, Syria. Follow-up roentgenograms on twelve of these patients show progress, arrest, or regression of the disease. These cases are compared with two control series, comprising fifty patients with stiffness of the back not caused by vertebral disease, and fifty patients with lesions confined to the vertebral symphyses, with or without symptoms. The details are tabulated and analyzed on charts and graphs. Roentgenograms, drawings, and clinical photographs are included. Biopsy material was difficult to obtain, except from autopsies on patients with advanced stages of the disease.

The roentgenographic findings are divided into three stages. Stage I, the early phase, shows a stippled or diffuse rarefaction of the articular processes. The facets have indistinct outlines. The intervening joint space is slightly narrowed or clouded. Stage II, the moderately advanced stage, shows roughening or scalloping of the facets with definite narrowing of the joint space. Characteristically, the articular processes appear increased in density and the vertebral bodies appear rarefied. Slight or incomplete ossification of the ligaments may be present at this time. In Stage III, the terminal phase, bony ankylosis between the apophyseal joints develops. An interesting point here is the difference between complete bony ankylosis and encircling ankylosis, the latter consisting of a bony bridging confined to the articular margins of the facets with the central parts still preserved. Although the ossification of the ligaments may be absent in the third stage, it is usually extensive when present.

Many sources of error are involved in this type of study. The roentgenographic technique, which is described in the author's previous papers, requires accurate positioning of the patient and the employment of certain tube angulations. Skill is required in interpreting the films because of the many ambiguous shadows resulting from varying directions of the facets, overlapping of the curved planes of the facets, and shadows of extravertebral structures. A study of the reproduced roentgenograms reveals that it may be difficult to duplicate exactly the posterior oblique projections for the purpose of comparative studies. Differences in size, position, and amount of cortical bone often cause normal articular processes of the same vertebra to vary in density. Oppenheimer urges care and conservatism in interpretation.

A correlation of the clinical findings shows that rigidity is found in all patients with rheumatoid apophyseal lesions. Local pain diminishes as the disease progresses. Radicular pain was found in one-third of all cases. Radicular neuritis, however, is more frequently caused by lesions of the discs.

Successful results from roentgenographic treatment were observed in seventeen patients who were not relieved by the usual therapeutic measures. The author recommends doses of forty to sixty roentgen units to the entire spine over a period of one week until a total of 240 roentgen units is reached. The radiation is delivered through portals, fifteen by fifteen centimeters in size, at an intensity of eighteen to twenty-two roentgen units per minute, using 135 to 150 kilovolts, five milliamperes, twenty-five centimeters target-skin distance, with filters of 0.5 millimeters of copper and 1.0 millimeters of aluminum. Additional treatment is advised if symptoms recur. The author believes that this type of therapy is probably more effective than the techniques requiring higher voltage as used by other workers in this disease.—*Richard C. Batt, M.D., Berlin, New Hampshire.*

CHEMOTHERAPY IN OSTEOMYELITIS. Abraham O. Wilensky. *The American Journal of Surgery*, LVII, 76, 1942.

This is a summary on the use of the sulfonamide drugs in osteomyelitis, acute and chronic, based on reports in the literature, reports of other surgeons and pediatricians, and the author's own experience. He analyzes the use of this drug in acute osteomyelitis, during the stage of bacteraemia, chronic stage, *et cetera*.

In general, he states that the use of the drugs has not given the consistently good results it has in medical conditions, especially pneumonia. Best results, he believes, can be obtained in the stage of bacteraemia by maintaining a level of fifteen milligrams in 100 cubic centimeters of blood for a consistently long period. The effect of this management of the local lesion is doubtful.—*T. G. Greteman, M.D., Iowa City, Iowa.*

THE USE OF MYOTOMY IN THE REPAIR OF DIVIDED FLEXOR TENDONS. Lester Blum. *Annals of Surgery*, CXVI, 461, 1942.

To release muscle tension in the repair of divided flexor tendons, the author performs a myotomy, and severs the tendon prolongation, leaving about one inch of muscle fibers. The procedure has the following advantages:

1. It is quite simple and requires but a few minutes.
2. The handling of the divided tendon ends is facilitated by eliminating the tension which ordinarily complicates the repair.
3. The danger of disruption of the suture line is obviated.
4. Much finer suture material can be used in the tenorrhaphy.
5. The tendon ends can be more completely débrided and trimmed without fear of sacrificing too much tendon.
6. The finger can be splinted in extension postoperatively with only the wrist flexed. This makes it far easier for function to be regained than if the finger has been held in acute flexion for several weeks. Also there is less likelihood of adhesions between the site of the tendon suture, which is withdrawn into the uninjured tendon sheath, and the site of injury to the sheath and skin.
7. Tendon grafts to bridge short intervals are unnecessary.
8. The myotomy wound heals spontaneously and completely, with no residual defect of muscle strength.

Ten case reports are included.

LUXACIÓN EXPUESTA DE LA ARTICULACIÓN TIBIOTARSIANA (Compound Dislocation of the Ankle Joint). Bernardo Dell'Oro y Nalla Salim. *Boletines de la Sociedad de Cirugía de Rosario*, IX, 144, 1942.

The authors report a case of compound dislocation of the ankle in a thirty-five-year-old man who was injured in a game of amateur football, and was brought to the Hospital at eleven o'clock Sunday morning. On examination there was a wound about four centimeters long over the internal malleolus, through which the entire internal malleolus was protruding. Careful examination revealed no evidence of fracture, and, since it was Sunday morning, and therefore impossible to take a roentgenogram, it was decided to go ahead with the treatment without this advantage. Using a local anaesthetic, the wound was carefully cleaned, draped, and then enlarged, so that the whole ankle joint could be fully and easily explored. The joint and wound were carefully washed and cleaned, and then the ligaments and joint capsule were repaired. A tight closure without drainage was done. Postoperatively the patient was given antitetanus and antigas-bacillus serum. No infection developed. The cast which was applied postoperatively was removed at the end of nineteen days, and since there was still some pain over the internal malleolus, another cast with a walking iron was applied, and the patient was sent home. It is interesting to note that the case has been reported before time has elapsed for a follow-up. The author of the case report ends up with a plea for immediate and careful treatment of compound fractures and dislocations, even if they occur at inconvenient times. He says they should be treated with at least as much care as an acute abdomen.—*Captain Louis W. Breck, Medical Corps, Fort Sam Houston, Texas.*

THE "COMBINED OPERATION" IN LOW BACK AND SCIATIC PAIN. R. K. Ghormley, J. Grafton Love, and H. Herman Young. *The Journal of the American Medical Association*, CXX, 1171, December 12, 1942.

The combined operation is a combination of exploration of the spinal canal and bone grafting to bridge the affected parts in patients suffering from low-back pain. The number of combined operations has been steadily increasing at the Mayo Clinic, rising from 1 per cent. in 1937 to 14 per cent. in 1940. The reason for this is that the orthopaedic consultants see all patients suspected of having an intraspinal lesion of the intervertebral-disc type before operation is done.

A careful history is taken to evaluate the early symptoms for evidence of the static type of back pain relieved by rest, and superimposed evidence of protruded disc is made. Evidence for or against fusion is not determined solely by roentgenographic findings. In a group of seventy-seven patients, in whom results of myelographic examination were positive, spinograms were positive in forty-nine cases, and in five cases the protruded discs were found with radiopaque oil, making a total of fifty-four of the seventy-seven patients.

In a group of sixty-two patients for whom results of exploration were negative, results of spinograms were positive in twenty cases, and in one case results of examination with radiopaque oil were positive. This discrepancy between the results of the spinogram and the results of surgical exploration was due to the interpretation of hypertrophied ligamentum flavum as protrusion of the intervertebral disc in cases in which the results of exploration had been negative.

Tibial grafts were used in closing the laminectomy defects, as well as for stabilizing the low back, as it was felt that these were superior to chip grafts, and also because they could be obtained from the tibia at the time the neurosurgeons were doing the laminectomy. Plaster fixation was not employed postoperatively, and a normal schedule was generally reached by the end of three or four months after operation.

In a tabulation of end results, 64 per cent. of the patients had good results, 25 per cent. fair, and 11 per cent. poor results. In an analysis of some of the fair and poor results, three cases were found in which the graft was unsatisfactory; one case of infected graft and questionable fusion; one of psychoneurosis; and one on whom compensation had not been settled. It is felt that laminectomy plus fusion need not limit a patient's career as far as his work is concerned. Protruded discs, as far as the authors were able to ascertain, have not recurred after fusion.

An interesting abstract of discussion follows this well-written article.—*H. H. Beckering, M.D., Dallas, Texas.*

HERNIATED INTERVERTEBRAL DISK. A STUDY OF THE IODIZED OIL COLUMN. THE PROCAINE TEST IN DIFFERENTIAL DIAGNOSIS FROM REFLECTED SCIATIC PAIN. Orlan R. Hyndman, Arthur Steindler, and Julius Wolkin. *The Journal of the American Medical Association*, CXXI, 390, February 6, 1943.

The authors discuss low-back pain accompanied by sciatic radiation as due to lumbosacral-root compression and myofascial trauma.

The most common causal factor of lumbosacral-root compression is herniated intervertebral disc. The pain is referred, and is ordinarily accompanied by such diagnostic signs and symptoms, especially for a herniated disc below the fourth or fifth lumbar vertebra, that myelography is seldom necessary to establish a diagnosis. In the occasional equivocal case in which myelography is desired, iodized poppyseed oil is the medium chosen, and by using five cubic centimeters of the oil, the smallest, laterally placed herniations will be indicated in the roentgenogram in a very high percentage of cases.

In a small percentage of patients who present definite symptoms and signs of root compression, including an absent Achilles-tendon reflex, no herniated disc, concealed or otherwise, is found. In this type of case, the authors advise complete removal of the fourth and fifth lumbar laminar arches and their accompanying ligamenta flava, and partial unroofing of the intervertebral canals of the fifth lumbar and first sacral roots, and report very favorable results following such procedure.

If a tender locus is present over the lower part of the back, sacrum, or buttocks, local anaesthetization of the locus will not abolish the signs or symptoms of lumbosacral-root compression, but it will temporarily abolish the pain of myofascial trauma; therefore the procaine test (procaine anaesthetization) is considered a valuable test in the differentiation of referred and reflex sciatica. A positive procaine test indicates the success of immobilization either by conservative methods or by surgical fusion.—*John K. Coker, M.D., Dallas, Texas.*

Effect of Sulphonamide Preparations on Experimental Infected Wounds. Frank Hawking. *The Lancet*, II, 507, October 31, 1942.

Hawking, who has prepared several previous papers on the local use of the sulphonamides, has once again presented some interesting findings. Using experimental wounds in rabbits, a study was made of the proposal that, when battle conditions made excision of wounds impracticable, wounds should be filled with some semifluid preparation of a sulphonamide, and then covered with an occlusive dressing to prevent exogenous infection.

Therapeutically, the best results of all were obtained with the preparation of microcrystal sulphathiazole suspended in saline; with sulphanilamide, which is more soluble and more rapidly absorbed, better results were obtained with oily preparations than with aqueous ones.

Histologically, the presence of an oil in the wounds caused undesirable tissue reactions. Of the oils tested, cod-liver oil was especially bad in this respect, liquid paraffin was moderately bad, while cotton-seed oil was the least harmful. The preparation causing the least damage of all was the microcrystaline preparation of sulphathiazole, which was also the most effective therapeutically.—*Lenox D. Baker, M.D., Durham, North Carolina.*

Vitamin C and Repair of Injured Tissues. Geoffrey H. Bourne. *The Lancet*, II, 661, December 5, 1942.

The author presents evidence to support the theory of Salter and Aub that adequate vitamin C is necessary for repairing damage to both soft and hard tissues. Small holes were bored in the femora of guinea pigs receiving injections of sodium alizarin sulphonate. The repair tissues stained strongest in those pigs receiving injections of two milligrams daily of vitamin C for two weeks, less intensely in those receiving five-tenths of a milligram, and not at all in those receiving no vitamin C.

He concluded that vitamin C may play three important rôles in the regeneration of bone: It may promote activity of fibroblast cells and possibly their differentiation into osteoblasts; it may favor the attachment to each other of the polypeptide chains which make up the constituent collagen fibers of the bone matrix; and, by promotion of phosphatase activity, it may aid in the precipitation of bone salts.—*Lenox D. Baker, M.D., Durham, North Carolina.*

Zinc Peroxide, Proflavine and Penicillin in Experimental *Cl. Welchii* Infections. James McIntosh and F. R. Selbie. *The Lancet*, II, 750, December 26, 1942.

The authors used bacteria suspensions prepared from eighteen-hour anaerobic cultures of a highly virulent clostridium welchii organism. One tenth of a cubic centimeter of the suspension contained 2000 to 4000 million clostridium welchii, and was sufficient to kill all untreated mice within twenty-four hours. Zinc peroxide which acts as an oxidizing chemical was found to possess only an antiseptic action, because, when its application to the infected site was delayed, it failed to exercise preventive action. It was felt that proflavine was of greater value than sulphanilamide, and at least as good as sulphathiazole as a local prophylaxis. Penicillin injected at the site of infection within three hours of infection was found to be a powerful prophylactic against clostridium welchii infection in mice, and is superior to proflavine and the sulphonamides in this respect.—*Lenox D. Baker, M.D., Durham, North Carolina.*

THE TREATMENT OF GAS GANGRENE. W. Hugh Smith. *The Medical Journal of Australia*, I, 100, 1942.

The most violent cases of gas gangrene are those in which the bone is also affected. If clostridium welchii occurs in association with streptococcus pyogenes, the infection becomes more violent.

The wound shows a faint bluish discoloration, and has a serosanguinous discharge, and mousy, musty smell. Roentgenograms may reveal gas bubbles very early. Early and thorough cleansing of the wound is the best way to prevent gas gangrene. Excision of the dead muscle is important. The muscle incision must be made longitudinally as the vessels enter the muscle proximally. Syringing the wound should be avoided as it may carry the infection into the deeper tissues. Amputation, according to many authors, is worse than roentgen irradiation. Serum, according to Weinberg, reduces mortality from 30 to 80 per cent. to 6.7 per cent. Twenty thousand units should be given intravenously, and 20,000 into the muscle. The value of chemotherapy is inconclusive. Roentgen-ray treatment, in Kelly's statistics, resulted in 11.3 per cent. mortality. Irradiation was performed twice daily for three days.—*Aladár Farkas, M.D., Iowa City, Iowa.*

A LINHA EPIFISÁRIA E SUA IMPORTÂNCIA EM CIRURGIA (The Epiphyseal Line and Its Importance in Surgery). Bruno Valentin. *Revista Brasileira de Cirurgia*, Setembro, 1941.

A short historical review of the relation of the growth of bone and the functions of the epiphyseal line is given. Emphasis is placed on the work of Ollier, who was the first to mention the importance of avoiding the epiphyseal line during operative interventions, and the disturbances of growth following injury to the epiphyseal line.

The author shows a series of interesting photographs, taken in his clinic, illustrating the disastrous consequences following operations through or near joints in children. The author also describes deformities which involve the epiphyseal line, and which are produced by multiple cartilaginous exostoses and enchondromata.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

FORMAS RARAS DA TUBERCULOSE DOS OSSOS E DAS ARTICULAÇÕES (Osteíte tuberculosa múltipla cistóide e tuberculose cística dos ossos) [Rare Forms of Tuberculosis of the Bones and Joints (Multiple Cystic Tuberculous Osteitis and Cystic Tuberculosis of Bones)]. Bruno Valentin. *Revista Brasileira de Cirurgia*, Janeiro, 1942.

The author describes a case of multiple cystic tuberculous osteitis in a child aged one and one-half years, in which the presence of tuberculous bacilli was proved by bone puncture. The condition is a slowly progressive rare form of osteotuberculosis involving symmetrically both hands and feet, and is always associated with lupus pernio. The roentgenogram shows cystlike bone rarefaction in the phalanges and metacarpals. This affliction must be differentiated from the more virulent forms of cystic tuberculosis of the bone, and from spina ventosa. The author advises no special treatment.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

LUXACIÓN TRAUMÁTICA DE LA CADERA EN EL NIÑO (Traumatic Dislocation of the Hip in Children). León Velasco Blanco y Eduardo Marcelo Echegaray. *La Revista de Medicina y Ciencias Afines*, IV, 678, 1942.

An extensive review of the European and American literature on the subject of traumatic dislocation of the hip in children is given, and various European authorities, who uniformly agree as to the great rarity of the lesion, are quoted. The authors of this paper state that the case being reported is the only one they have ever seen in an extensive experience with injuries in children. They point out that great force is necessary to produce the dislocation, and that the mechanism of injury is the same in children as in adults. Posterior dislocation of the head of the femur is the most common type. The differential diagnosis from fracture of the neck of the femur is not easily made on examination, and the roentgenogram is all important in making the diagnosis. The authors lay great stress on the early diagnosis of the condition, for they feel that reduction

is much easier immediately after the dislocation occurs. Manual reduction under general or spinal anaesthesia should be done. Following reduction, the leg should be immobilized in extension and slight abduction for ten days, and in a few days more the child may be allowed up. A case is reported in detail by the authors. The child, a boy, aged eight years, had fallen ten days previously while playing, with another boy falling on top of him. The classical manipulation was done and reduction was accomplished on the second attempt. The patient had been followed for eighteen months, and he was still entirely normal at that time. The article is illustrated with roentgenograms made before and after reduction, and after eighteen months; the latter shows a normal hip. There is a good bibliography of thirty-seven references, which would prove useful to anyone reviewing this subject.—*Captain Louis W. Breck, Medical Corps, Fort Sam Houston, Texas.*

DEGENERACIÓN AMOILOIDEA Y TUBERCULOSIS (Tuberculosis and amyloid degeneration). L. C. Topez, N. C. Calvo, J. M. Rodriquez Jimenex, D. C. Ledon. *Revista de Tuberculosis*, V, 102, 1941.

These authors report twenty-one cases of amyloid degeneration found in 200 autopsies performed upon patients with tuberculosis at the Hospital La Esperanza, in Havana. The organs involved in order of frequency were liver, spleen, kidney, gastro-intestinal tract, arteries, and pancreas. The Congo-red test was positive in all of these cases of marked hypoproteinaemia. The prognosis is always fatal.—*John G. Kuhns, M.D., Boston, Massachusetts.*

A TREATMENT OF FRACTURED CLAVICLE BY TRACTION. Fred G. Hodgson. *Southern Medical Journal*, XXXV, 1079, 1942.

This is not a treatment for the ordinary simple fracture of the clavicle, but for those in adults, especially women, where an accurate replacement and maintenance is desired without operation. A number of these patients have to remain in bed on account of shock or of other complications, and others do not object to remaining in bed if they are assured of a good result.

A bed is prepared with a fracture board under the mattress. The head of the bed is raised on shock blocks or a chair. A figure-of-eight bandage is applied to both shoulders with padding in the axillae. On the injured side this bandage is fixed to the head of the bed. As the body slides down in the bed, due to gravity, the fracture is reduced and maintained in place. Usually no anaesthetic is required. Morphia or a sleeping powder is given the first night. The article is illustrated.

THE TREATMENT OF SLIPPED UPPER FEMORAL EPIPHYSIS. W. K. West. *Southern Medical Journal*, XXXV, 1082, 1942.

In a case of mild deformity, reduction is performed under anaesthesia by gentle manipulation, and a double hip spica is applied and is worn three months. This is followed by physiotherapy. In cases where there is a definite union of the epiphysis with mild deformity, open reduction is done. The deformity is corrected using a wood-carving chisel to separate the head and neck. After reduction a double plaster hip spica is worn for three months, then protection for three months longer. The author does not consider a Smith-Petersen nail necessary to maintain the reduction after open operation in all cases, but three cases are reported where the Smith-Petersen nail was used following osteotomy of the neck of the femur. In cases where the deformity is marked, union solid, and the head deformed, a subtrochanteric osteotomy is advised. In one case, an arthroplasty of the hip was done with fair result.

In some cases, skeletal traction with a pin through the lower third of the femur will assist in reducing the displacement.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*